

MARYLAND GEOLOGICAL SURVEY.
WILLIAM BULLOCK CLARK, State Geologist.

THE GEOLOGY
OF
PRINCE GEORGE'S COUNTY, MARYLAND
AND
THE DISTRICT OF COLUMBIA



A Dissertation submitted to the Board of University Studies of the Johns Hopkins University
in conformity with the requirements for the Degree of Doctor of Philosophy

BY

BENJAMIN LEROY MILLER

THE JOHNS HOPKINS PRESS
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INTRODUCTORY.

The geologic formations represented in Prince George's County range in age from Archean to Recent. Deposition, however, has not been continuous and many gaps occur, that between the Archean and Cretaceous covering a very long interval of time. None of the larger geologic divisions since Jurassic time are entirely unrepresented. Periods when there was deposition over part or the whole of the region were separated by other periods of greater or less duration in which the entire region was above water and erosion was active. The deposits of all the periods except the Archean and Pleistocene are similar in many respects. With a general northeast-southwest strike and southeast dip, each formation disappears by passing under the next later one. In general also the shore line during each successive submergence evidently lay a short distance southeast of the position

System.	Series.	Group.	Formation.
Quaternary	Pleistocene	Columbia	{ Talbot. Wicomico. Sunderland.
	{ Pliocene (?)		Lafayette.
Tertiary	{ Miocene	Chesapeake	{ Choptank. Calvert.
	{ Eocene	Pamunkey	{ Nanjemoy. Aquia.
	{ Upper Cretaceous....		{ Monmouth. Matawan. Magothy.
Cretaceous	{ Lower Cretaceous....	Potomac	{ Raritan. Patapsco. Arundel. Patuxent.
Archean			Granite gneiss.

it occupied during the previous submergence. There are a few exceptions to this, however, that will be noted in the descriptions which follow. The traveler passing from northwest to southeast crosses the outcrops of the formations in the order of their deposition. The general sequence is shown in the accompanying table.

THE CRYSTALLINE ROCKS.

The exposures of crystalline rocks within the limits of Prince George's County are confined to the deeper valleys along the northern border of the county. Elsewhere the crystallines are completely covered by the unconsolidated deposits of the Coastal Plain. Of the different varieties of rock developed in the contiguous portions of the Piedmont, only the granite gneiss and gabbro are exposed within the confines of the county. Granite gneiss, diorite, serpentine, gneisses, and schists are exposed within the District of Columbia and in near-by portions of Montgomery and Howard counties.

The oldest rock of the region is the Baltimore gneiss, or Carolina gneiss, as it was earlier named by Keith in his description of the rocks of Washington and vicinity. According to Keith—

"The formation is composed of alternating layers of gneiss and schist of a prevailing gray color, dark bluish gray where fresh, and greenish or yellowish gray where weathered. Individual bands vary from a few inches up to several feet in thickness, with an average of perhaps less than a foot The original nature of the gneiss, whether igneous or sedimentary, is quite unknown."

GRANITE GNEISS.

The granite gneiss is the first of three classes of granite which intruded the Baltimore gneiss and one of the two crystalline types found within the limits of the county. Like the gneiss, it is almost always gray in color, and the minerals have been arranged in approximately parallel lines as a result of the metamorphism which the original granite suffered. There is, however, no true banding, as in the Baltimore gneiss, and the degree of schistosity varies from place to place. The black patches found in the granite gneiss are usually regarded as inclusions of Baltimore gneiss torn from the latter by the former at the time of intrusion.

Outside the county, within the District and elsewhere, are other granites and diorites which might be confused with the latter, al-



VIEW SHOWING SILICIFIED CYCAD TRUNK, *Cycadeoidea marylandica* (Fontaine), Cap. and Solms., FROM THE PATUXENT FORMATION OF PRINCE GEORGE'S COUNTY.



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though the granites are less schistose and the diorites show hornblende more abundant than mica.

GABBRO.

Gabbro is the second type of crystalline rocks found within the county. It is exposed in the valley of the Patuxent near Laurel and has been quarried to some extent on the Howard County side, just above the Laurel bridge. When fresh and unmetamorphosed it is a dense bluish to greenish black rock of granular texture and extreme toughness. When metamorphosed it loses its granular texture, becomes more and more platy through the development of fibrous hornblende and chlorite. When the gabbro weathers it forms rounded boulders with dark rusty surfaces, well known as "nigger heads." The distribution of this type is usually marked by deep red and brown clay soils, which, though somewhat heavy, are strong and fertile.

The crystalline rocks, as a complex unit, extend southeastward beneath the Coastal Plain, and serve as the basement on which rest the gravels, sands and clays which occupy practically all of the surface of the county.

THE LOWER CRETACEOUS FORMATIONS.

THE POTOMAC GROUP.

The Potomac group of the Coastal Plain consists of highly colored gravels, sands, and clays which outcrop along a sinuous line from Pennsylvania to Richmond, passing near the cities of Philadelphia, Wilmington, Baltimore and Washington. The Potomac deposits are of great value because of the excellent brick clays which they contain. All three of the formations which are now recognized as composing this group are represented within Prince George's County.

The Patuxent Formation.

The Patuxent formation received its name from Patuxent River, in the basin of which the deposits of this horizon were first recognized as an independent formation and systematically studied. Careful work showed that the deposits formerly included in the Potomac

formation were readily separable into distinct formations on the basis of unconformities and fossil content.

Areal Distribution.—The area of outcrop of the Patuxent formation extends from the mouth of Piscataway Creek up the west shore of the Potomac River to and beyond Anacostia River which, with its tributary, Indian Creek, constitutes for the most part the eastern boundary of the formation. It underlies the greater portion of the City of Washington and extends as almost continuous outcropping beds to Laurel.

Character of Materials.—The materials composing the Patuxent formation are extremely variable, although prevailing are arenaceous. Buff and light-colored sands, both fine and coarse, predominate, while beds and lenses of clays and gravels occur less commonly. The sandy strata, which usually contain considerable amounts of kaolinized feldspar and are therefore an arkose, were called by Rogers "feldspathic sandstone." The sands are in many places cross-bedded, and with the gravels are here and there indurated by oxide of iron to form ferruginous sandstones. The sands contain small and large lenses of clay, which are commonly light in color, though locally they are highly colored by iron compounds.

The following section exposed in the northwestern part of Washington, is characteristic of the formation:

Section in northwestern part of Washington, D. C.

SUNDERLAND:	Feet.
Red loam.....	2
Stratified gravels, sands, and clays.....	23
PATUXENT:	
Coarse white arkosic pebbly sand, slightly lignitic; small pellets of white clay, and a lens of light greenish-drab sandy clay 5 feet in thickness. The strata show both horizontal and cross bedding. Amount exposed..	15
	40

Paleontologic Character.—The organic remains of the Patuxent formation are neither plentiful nor varied. No animal remains have thus far been found in deposits of this age within Prince George's County, but a teleost fish has been reported from beds of apparently the same age on James River in Virginia. Plant remains are equally rare and consist chiefly of the lignitized and silicified trunks of

conifers and cycads. During the excavating for the new reservoir in Washington a silicified trunk 50 feet in length and several feet in diameter was found in beds belonging to the Patuxent formation. Another similar trunk about 4 feet in diameter was found in the vicinity of the Maryland Agricultural College.

Strike, Dip and Thickness.—The strike of the Patuxent formation in this county is almost due north and south along the Potomac River, but at Washington it changes to a northeast-southwest direction.

The dip of the Patuxent, as well as of the overlying beds of the Potomac group in Maryland, ranges in direction from east-southeast in its more southerly exposures to south-southeast farther north. The normal dip of the basal beds of the formation reaches about 60 feet to the mile. In the vicinity of the "Fall line," which is toward the landward margin of the Patuxent outcrop, the dip of the basal beds is considerably greater than this. Southeast of Washington it ranges from 50 to 75 feet, but near the "Fall line" it amounts to about 90 feet to the mile.

The observed thickness ranges from a few feet to 340 feet, increasing toward the east. On the basis of well data the estimated maximum thickness is about 500 feet.

Stratigraphic Relations.—The Patuxent formation overlies the granite-gneiss, of Archean age, and is overlain unconformably by the Arundel formation. In many places where the Arundel has been removed by erosion the Patuxent is overlain unconformably by clays, sands, and gravels belonging to the Columbia group.

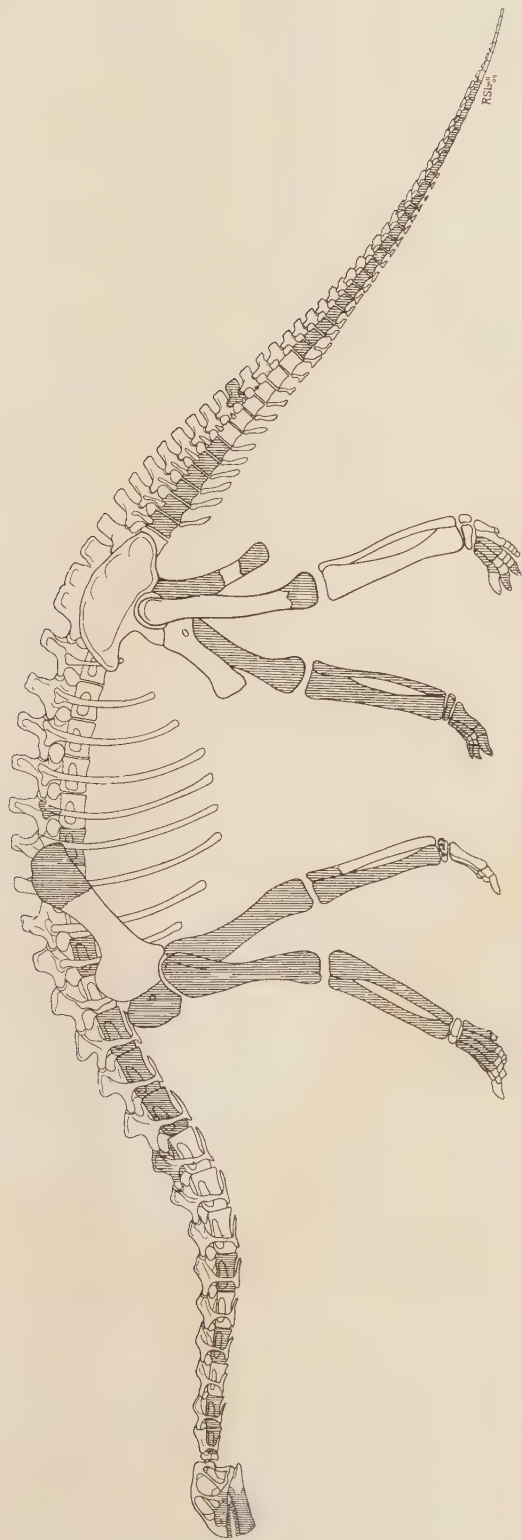
The Arundel Formation.

The Arundel formation received its name from Anne Arundel County, where the deposits of this age are typically developed and well exposed.

Areal Distribution.—The outcrops of the Arundel formation within Prince George's County are confined entirely to its northwestern portion between Washington and Laurel, but it is believed to underlie the greater portion of the county south and east of Anacostia

River. In its wider distribution the formation occupies a comparatively narrow, irregular and much interrupted belt extending from Washington to Bush River, near the head of Chesapeake Bay. There are also outliers of less importance to the north and south of the general outcrop. At Capitol Hill, Washington, a well boring, after passing through about 50 feet of Recent and Pleistocene materials, penetrated 131 feet of exceedingly tough drab and highly colored lignitic clays which apparently belong to the Arundel formation. Beneath these clays the boring passed into the Patuxent sands and gravels. Clays probably belonging to the Arundel formation were encountered in an excavation for a deep sewer in the vicinity of Anacostia bridge.

Character of Materials.—The materials composing the Arundel formation are diverse in lithologic character. They comprise large and small lenses of drab and iron-stained clays which in many places contain concretions, flakes or ledges of earthy iron carbonate and cellular limonite. Iron pyrite and gypsum occur less commonly. The clays may be either laminated, carrying more or less sand, or massive, with surfaces exhibiting slickensides. Logs of lignite, usually deposited in a horizontal position and greatly compressed, are found embedded within the formation. These logs are in places massed in well-defined beds of such thickness and extent as to be of local use to the miners for fuel. Occasionally large stumps are discovered standing buried in the position in which they grew, with the roots and trunks fossilized by iron carbonate and iron sulphide. Seeds of plants are found near some of these beds. Locally the clay is charged with comminuted lignite, when it is termed "charcoal clay" or "charcoal ore." Here and there this "charcoal clay" contains fossil bones. Near Muirkirk, Hatcher obtained from it dinosaurian and other organic remains. Where the Arundel formation has been exposed to the atmosphere the carbonate ores have at some places changed to the hydrous oxides of iron to a considerable depth. Where this has occurred, clays which were originally drab colored have become red or variegated. Along the western margin of the formation the materials become arenaceous and locally consist of lenses of sand.



RESTORATION OF THE COMMONEST CRETACEOUS DINOSAUR OF PRINCE GEORGE'S COUNTY, *Coelocrocodylus nanus* Marsh, (after Lull).— $\frac{1}{18}$ NATURAL SIZE.

The section exposed at the Muirkirk iron mine, where the best dinosaurian remains thus far obtained from this formation were found, is as follows:

<i>Section at iron mine, Muirkirk, Md.</i>	
RECENT:	Feet.
Surface wash, consisting of loam and gravel.....	10
PATAPSCO:	
Sands and gravel, indurated in places by iron oxide and containing silicified trunks of conifers and cycads....	10
Massive and stratified, mottled and variegated clays and sandy clays with redeposited nodules of iron carbonate and some limonite, pebbly at base, flanking the subjacent member.....	5 to 15
ARUNDEL:	
Massive blue clay with flakes and nodules of iron carbonate and containing bones and teeth of dinosaurs at base.....	20 to 40
Highly lignitic lens of clay ("charcoal ore").....	2
Tough blue clay containing iron carbonate.....	15
PATUXENT:	
White sand; amount exposed.....	10
	72 to 102

Paleontologic Character.—The fossil flora of the Arundel formation includes ferns, cycads, conifers, and possibly dicotyledons. By far the most common of these are the conifers, with whose lignitized trunks the clays are, in places, densely packed, forming local beds of lignite. Leaf impressions are also present in the iron ores.

The animal remains, while nowhere abundant, represent a variety of forms. They include worm or insect borings, pelecypods, gastropods, dinosaurs, turtles, and crocodiles. The Dinosauria, of which a number of species have been recognized, greatly predominate.

Strike, Dip, and Thickness.—The strike and dip of the Arundel formation are approximately the same as those of the Patuxent. The usual dip is 40 to 50 feet to the mile, but there is a well-marked increase near the "Fall line," where the average is about 72 feet to the mile. At Washington it is 66 feet to the mile. The maximum thickness of the Arundel is 125 feet or more and the formation thins out and disappears in some areas.

Stratigraphic Relations.—The Arundel overlies the Patuxent unconformably and is overlain unconformably by the Patapsco.

The Patapsco Formation.

The Patapsco formation received its name from Patapsco River, in whose valley it is typically exposed.

Areal Distribution.—The Patapsco has a more extended development within this county than either of the two preceding formations. Its outcrop is confined to the northwestern portion of the county, extending from Anacostia northeastward to the boundary and occurring in narrow bands near the headwaters of a few of the streams south of Anacostia. To the southeast of this outcrop it is supposed to extend over the entire county, underlying all the formations of later age. In its wider distribution the Patapsco formation has been recognized in discontinuous outcrops from the valley of Schuylkill River, near Philadelphia, to the valley of the Rappahannock, in Virginia.

Character of Materials.—The Patapsco formation is composed chiefly of highly colored and variegated clays, interbedded with sandy clays, sands, and gravels, the materials of different kinds grading into each other both horizontally and vertically. In many places the arenaceous material in the vicinity of clay beds is indurated to a conglomerate or rough, irregular, pipelike concretionary mass called "pipe ore." The variegated clays exhibit a great variety of rich and delicate tints in irregular patterns. In places they grade downward or horizontally into massive clays of chocolate, drab, and black tones, locally carrying lignite and pyrite and in some places containing iron ore and leaf impressions. The sands, which are very commonly cross-bedded, here and there carry decomposed grains of feldspar and pellets of white clay. A red ocher that is locally known as "paint rock" or "paint stone" is not uncommon, and limonite with botryoidal surfaces is found at various horizons.

Paleontologic Character.—The Patapsco formation contains a rich flora of ferns, cycads, conifers, monocotyledons, and dicotyledons. The dicotyledonous plants still constitute a minor element as compared with the other types of vegetation represented. The fauna of the Patapsco consists of a few molluscan shells and a single dino-

saurian limb bone. This latter fossil, which was found at the surface of the formation, was much worn and may have been redeposited from the Arundel.

Strike, Dip, and Thickness.—The general strike of the Patapsco corresponds practically to that of the formations which lie beneath it. The normal dip of the basal beds is southeastward at the rate of 35 to 40 feet to the mile, but the dip, like that of the preceding formations, increases toward the "Fall line."

The thickness of the Patapsco is somewhat variable, gradually increasing to the southeast. Within Prince George's County the outcropping thickness is about 100 feet. In some places, east of its outcrop, the formation is estimated to have a thickness of about 200 feet.

Stratigraphic Relations.—The Patapsco formation unconformably overlies the Patuxent or the Arundel formation of the Potomac group. It is overlain unconformably by the Raritan formation for the most part, although here and there in the region of its outcrop it is covered by Pleistocene deposits belonging to the Talbot or Wicomico formations.

THE UPPER CRETACEOUS FORMATIONS.

The Raritan Formation.

The formation receives its name from Raritan River, New Jersey, in the basin of which it is typically developed. It includes the deposits long called the Plastic or Amboy clays by the New Jersey Geological Survey. On the basis of the plant fossils, the formation has been regarded as representing the Cenomanian series of European geologists.

Areal Distribution.—In its wider distribution the Raritan formation has been recognized from Raritan Bay, New Jersey, to the basin of Potomac River. In the northwestern portion of the county it is represented by a narrow outcrop which crosses the area in a sinuous line from northeast to southwest and is also present near the headwaters of some of the creeks along the western margin of the county.

It dips under the overlying strata and is believed to extend over the entire central and eastern area of the county beneath the younger formations.

Character of Materials.—The Raritan consists of variable materials similar to those composing the Patapsco formation except that, in general, the clays are not so highly colored. White and buff sands; stratified sandy clays, light chocolate in color, in places containing leaf impressions; light-colored argillaceous sands and sandy clays ("fuller's earth"); and white, yellow, drab, bluish drab, and variegated clays all occur in deposits of this age. The drab clays are here and there lignitic and pyritiferous, and in places exhibit partings of sand indurated with mammillary limonite. Ledges of sandstone, indurated by iron oxide or silica, are common. One and one-quarter miles north of Collington white quartzitic sandstones represent this phase. Several acres are covered with these masses of hard rock, which have been used for structural purposes in the vicinity. Similar sandstones of Raritan age occur in several places in Anne Arundel and Baltimore counties. The light-colored sands show in many localities large blotches of red ocher, locally designated as "paint pots." The Raritan deposits can not everywhere be separated with ease from the underlying Patapsco strata, but there is much less difficulty in separating them from those of the overlying Magthy formation, which are much more uniform in character and less highly colored.

Paleontologic Character.—Both animal and plant remains have been found in the Raritan formation, but the known fauna is very scanty both in individuals and species, the flora being much more abundant. Logs of lignitized conifers exhibiting teredo borings have occasionally been found, and in New Jersey this formation has yielded some bones of a plesiosaur and various molluscan remains. No dinosaurian remains have thus far been found in Raritan strata.

The flora of the formation includes ferns, fronds of cycads, conifers, monocotyledons, and dicotyledons, the last-named being particularly conspicuous and relatively modern in aspect. The Raritan

has yielded no silicified trunks of cycads, so far as is definitely known.

Strike, Dip, and Thickness.—The strike and dip of the Raritan formation correspond closely with those of the Patapsco. The normal dip of the basal beds is about 30 feet to the mile, but this increases toward the "Fall line." Within this area of outcrop in Prince George's County the Raritan formation is relatively thin in comparison with its thickness farther northeast. The estimated maximum thickness toward the extreme eastern margin of the belt of outcrop in this county is about 100 feet. The thickness of the formation seems to increase toward the southeast beyond the line where it disappears beneath later deposits.

Stratigraphic Relations.—The Raritan unconformably overlies the Patapsco formation, and is separated from the overlying Magothy by another marked unconformity. In the region of its outcrop, Pleistocene deposits of the Talbot, Wicomico, and Sunderland formations overlie the edges of the Raritan and generally conceal the deposits from view except where erosion has removed these later beds.

The Magothy Formation.

The Magothy formation takes its name from the excellent exposures of the beds of this age along the Magothy River in Anne Arundel County and was characterized by Darton¹ in 1893. Later work in Maryland seemed to indicate that these deposits represented merely phases of deposition within the Raritan. On this supposition, the fossil plants found in them were supposed to be Raritan forms and the stratigraphic break was attributed to contemporaneous erosion. In New Jersey the Magothy deposits in the vicinity of Philadelphia were placed in the Raritan, while those in the region of Raritan Bay, under the name Cliffwood beds, were by some geologists included in the Matawan on account of the presence of glauconite and the great percentage of post-Raritan plants and marine invertebrates, and by others were placed in the Raritan. Recent studies of the fossils and careful stratigraphic work in the

¹Darton, Amer. Jour. Sci., 3d ser., vol. XLV, 1893, pp. 407-419.

field, however, have shown that the Magothy should be regarded as a distinct formation, on both stratigraphic and paleontologic grounds, and these transitional beds from New Jersey southward have been referred by Clark² to the Magothy formation as defined by Darton for the Maryland area.

Areal Distribution.—The Magothy formation outcrops in discontinuous areas in Prince George's County, extending from the Patuxent River valley in the vicinity of Priest Bridge southwestward to the Potomac River valley just beyond Congress Heights. It does not outcrop in a continuous belt because of an overlap of the Matawan, which is in some places sufficient to bring that formation in immediate contact with the Raritan. An occurrence of this kind can be seen about three-fourths of a mile west of Brightseat. The best exposures lie from half a mile to 3 miles west of Priest Bridge and along the west slope of Good Hope Hill from St. Elizabeth's to the junction of Benning and Bowen roads on the District line.

Character of Materials.—The Magothy formation is composed of extremely varied materials and may change abruptly in character both horizontally and vertically. Loose sands of light color are the most prominent constituents. These sands usually show fine laminations and locally considerable cross-bedding. The sand consists of coarse, rounded to subangular quartz grains which range in color from pure white to a dark ferruginous brown. At many places lenses or bands of brown sand occur within the lighter colored sands. Normally the deposits of sand are loose, yet locally the iron derived from this and adjacent formations has firmly cemented the grains together to form an indurated iron sandstone or conglomerate. A thin ledge of such a sandstone near the Catholic Church west of Priest Bridge forms a small waterfall in a tributary of Patuxent River. Just below Overlook Inn, on East Washington Heights, there is a ledge of massive brown sandstone of this character.

The argillaceous character of the Magothy is very prominent in some localities, although it is usually subsidiary to the arenaceous phase. The clay commonly occurs as fine laminae alternating with

²Clark, Amer. Jour. Sci., 4th ser., vol. XVIII, 1904, pp. 435-440.

the sand layers. Drab is the characteristic color of the Magothy clay, but here and there the presence of considerable vegetable remains renders it black. The vegetable material may be finely divided or may occur in the form of large pieces of lignite. Thus far no bright-colored clays have been recognized in the Magothy deposits.

The Magothy can usually be differentiated from the underlying Raritan formation by its lack of massive beds of brightly colored variegated clay, and by the greater variability in the character of its materials. It can be more easily distinguished from the overlying Matawan by the almost complete absence of glauconite (although small pockets of greensand have been found in the Magothy at a few localities), by its lack of homogeneity, and by its variations in color. Moreover, the Matawan in Maryland usually contains considerable amounts of mica in small flakes, whereas the Magothy contains little mica.

Paleontologic Character.—In this county the only organic remains thus far recognized in the Magothy are leaf impressions in the drab clays that occur in thin laminæ alternating with layers of sand. Berry¹ has recorded *Widdringtonites Reichii* from the Overlook Inn Road on Congress Heights, and large collections from near Brightseat and Pennsylvania Avenue extended are being studied at the present time. At Cliffwood Bluff, on the south shore of Raritan Bay, New Jersey, beds of this formation have yielded a considerable flora and a marine fauna. The flora studied by Berry¹ is notably varied, over 100 species having been described. The flora presents many points of similarity to that of the Raritan, yet it contains many new species of forms characteristic of post Raritan formations in other regions. The most common fossil plant of that locality is represented by the imperfectly petrified cones of *Sequoia gracilima*. Other common species are *Cunninghammites squamosus*, *Dammara cliffwoodensis*, and *Sequoia reichenbachii*. Berry and Hollick

¹Bull. Torrey Club, vol. XXXIII, 1906, p. 169.

¹Bull. New York Bot. Gard., vol III, No. 9, 1903, pp. 45-103; Bull. Torr. Bot. Club, vol. XXXI, 1904, pp. 67-82; vol. XXXII, pp. 43-48; Ann. Rept. State Geol. New Jersey for 1905, pp. 135-172.

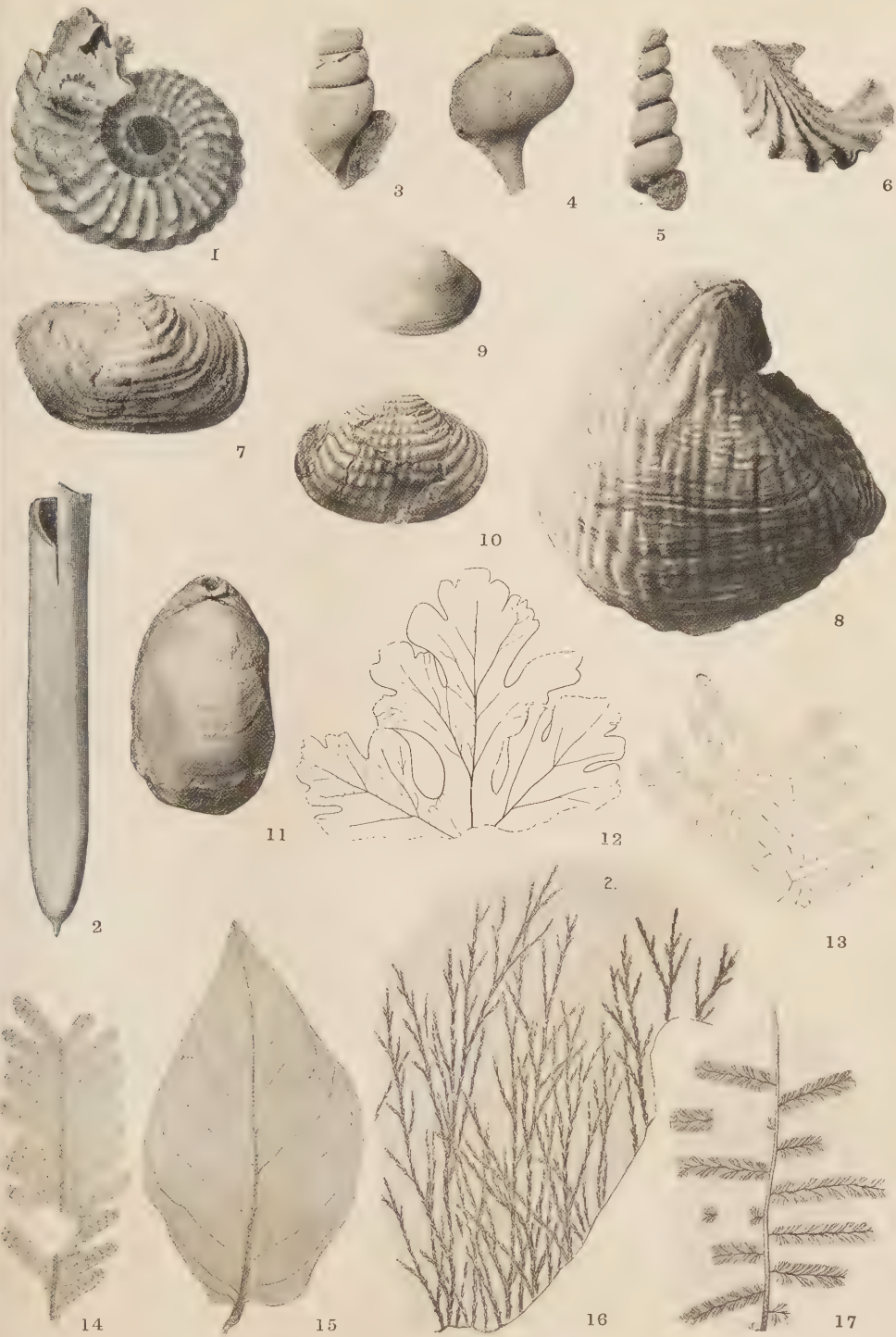
state that the flora of the "Cliffwood beds" shows Cenomanian characteristics.

The animal remains described by Weller² from the Magothy at Cliffwood Point were found in smooth concretionary nodules in a clay bed or lying loose on the beach, where they were left by the erosion of the clay beds that originally contained them. The fauna is characterized by the presence of great numbers of crustacean remains. Some portion of a crab seems to have been the nucleus about which the nodules were formed in almost every instance. Pelecypods, gasteropods, and cephalopods also occur. The most abundant forms are the following pelecypods: *Trigonarca* sp., *Pteria petrosa*, *Nuculana protexta* (?), *Yoldia evansi*, *Isocardia cliffwoodensis*, *Veleda lintea*, *Corbula* sp., and among the Crustacea *Tetracarcinus subquadratus*. These are of considerable importance, for, with the exception of a few forms from the Raritan in the same area, they are the earliest marine fossils found in the deposits of the Atlantic Coastal Plain. Weller states that the assemblage of forms constitutes a distinct faunule which more nearly resembles the faunule of the Matawan formation than any other.

Strike, Dip, and Thickness.—The strike of the Magothy formation is roughly parallel to that of the other Coastal Plain formations—from northeast to southwest. The dip is southeastward, at about 30 to 35 feet to the mile. Within Prince George's County the maximum thickness of the Magothy formation is about 40 feet, but in its wider extent the thickness is extremely variable, reaching a maximum of about 100 feet. This variability is due to greater deposition in some regions than in others and also to the removal of considerable Magothy material in certain areas.

Stratigraphic Relations.—The Magothy formation lies between the Raritan and Matawan formations and is separated from each by an unconformity. The line of contact between the Magothy and the Raritan is very irregular, indicating a considerable erosion interval between the times of their deposition. In many places the Magothy deposits fill pockets and old channels in the Raritan. The uncon-

²Ann. Rept. State Geol. New Jersey for 1904, pp. 133-144.



VIEWS SHOWING CHARACTERISTIC UPPER CRETACEOUS FOSSILS OF PRINCE GEORGE'S COUNTY.

- FIG. 1.—AMMONITES (Mortonicerus) VANUXEMI Morton.
- FIG. 2.—BELEMNITELLA AMERICANA (Morton).
- FIG. 3.—ANCHURA PENNATA (Morton).
- FIG. 4.—TURBINELLA ALABAMENSIS (Gabb).
- FIG. 5.—TURRITELLA VERTEBROIDES Morton.
- FIG. 6.—OSTREA FALCATA Morton.
- FIG. 7.—PANOEPA DECISA Conrad.
- FIG. 8.—EXOGYRA COSTATA Say.
- FIG. 9.—NUCULA PERCRASSA Conrad.
- FIG. 10.—CYMELLA BELLA Conrad.
- FIG. 11.—TEREBRATULA HARLANI Morton.
- FIG. 12.—CISSITES PARVIFOLIUS Berry.
- FIG. 13.—BRACHYPHYLLUM MACROCARPUM Newberry.
- FIG. 14.—MORICONIA AMERICANA Berry.
- FIG. 15.—MAGNOLIA HOLLIKI Berry.
- FIG. 16.—WIDDRINGTONITES REICHI (Ettings.) Heer.
- FIG. 17.—OSMUNDA DELAWARENSIS Berry.

formity between the Magothy and the Matawan is not so plainly marked; at many places these beds seem to be conformable. Indications of an erosion interval may be seen in some good exposures, however, and in the area of this county between Patuxent and Potomac rivers there is a marked unconformity of overlap. A short distance northeast of the District of Columbia line the Magothy is entirely lacking, its absence being due to an overlap of the Matawan, which rests upon the Raritan. Farther south it again makes its appearance. In the region of its outcrop the formation is in many places overlain by Pleistocene deposits.

The Matawan Formation.

The formation has received its name from Matawan Creek, a tributary of Raritan Bay, New Jersey, in the vicinity of which the deposits of this horizon are extensively and typically developed. The name was proposed by W. B. Clark¹ in 1894 and replaced the term Clay marls, previously used by the New Jersey geologists. The fossils of the Matawan formation furnish evidence of its Upper Cretaceous age.

Areal Distribution.—In Prince George's County the Matawan formation is found in a sinuous line extending from the Patuxent River valley near Priest Bridge southwestward to Fort Washington. Throughout this area it is exposed along the margins of the streams, but is covered by younger materials as it passes under the divides. The Matawan resembles the other Cretaceous formations in having a dip to the southeast which carries it beneath later deposits. It undoubtedly underlies the entire county to the southeast of the line of outcrop. In its broader distribution through the Coastal Plain, the Matawan formation extends as a continuous series of outcropping deposits from Raritan Bay to Potomac River.

Character of Materials.—The Matawan consists chiefly of glauconitic sand intimately mixed with dark-colored clay, while all through the material small flakes of mica are commonly found. In some places the deposits consist almost entirely of black clay; in

¹Clark, Jour. Geol., vol. II, 1894, pp. 161-177.

others, particularly where the upper beds are exposed, the arenaceous phase is predominant and the beds may consist entirely of sands varying in color from white to dark-greenish black. Where the glauconite decomposes, the iron oxidizes and the materials are stained reddish brown, and may even become firmly indurated by the iron oxide. Iron pyrite is also a common constituent and in places a small layer of gravel lies at the base of the formation. Although the Matawan contains varied materials it is much less variable than formations of the Potomac group or the Magothy formation, and throughout its extent in Maryland can generally be readily recognized by the prevailing dark-colored micaceous glauconitic sand of which it is chiefly composed.

Paleontologic Character.—Although the Matawan formation as a whole can not be regarded as extremely fossiliferous, yet it contains bands in which organic remains are present in great abundance. Such a band occurs in the cutting where the Chesapeake Beach Railway crosses Central avenue just east of the District line. In New Jersey as well as in Maryland the formation has yielded a varied fauna of foraminifers, pelecypods, gastropods, scaphopods, and ammonites.¹

Strike, Dip, and Thickness.—The formation strikes from northeast to southwest and dips southeastward at about 25 feet to the mile. The maximum thickness of the Matawan occurs in the Patuxent River valley and is about 40 feet. From this region the formation gradually thins toward the southwest until it is not more than 30 feet thick in the exposures along Henson Creek and about 20 feet thick in the Fort Washington hill. Like many other Coastal Plain formations, the beds thicken as they dip beneath later deposits, but the records of wells which have penetrated these formations in the eastern part of the county are too general to permit the determination of the amount of thickening.

Stratigraphic Relations.—In places a marked unconformity separates the Matawan from the underlying Magothy formation, but it is conformably overlain by the Monmouth. The separation between

¹Clark, Bull. Geol. Soc. America, vol. VIII, 1897, pp. 330-331.

the Matawan and Monmouth is made chiefly on the basis of change in lithologic character, but in part on that of the fossil contents. Although some organic forms range through both the Matawan and Monmouth, yet each formation has a few characteristic forms, the assemblage in each being on the whole fairly distinctive.

The Monmouth Formation.

The name Monmouth was first proposed for this formation in 1897 by W. B. Clark¹ when it was decided to combine in a single unit the deposits formerly included in the Navesink and Redbank formations. It was suggested by Monmouth County, New Jersey, where the deposits of this horizon are characteristically developed, and replaces the term Lower Marl bed of the earlier workers in New Jersey. On the basis of its marine fauna it is correlated with the Senonian of Europe.

Areal Distribution.—Within this county the Monmouth formation has only a slight development. It outcrops in the vicinity of Collington and eastward from that place to Patuxent River and thence southward along the banks of the stream to the vicinity of Governor Bridge. The Monmouth dips to the southeast and is believed to underlie the Eocene and Miocene deposits to the southeast of its outcrop. In its wider distribution the formation has been recognized by outcrops in a zone extending from the northeastern portion of this county to Raritan Bay in New Jersey.

Character of Materials.—The formation is prevailingly arenaceous in character and unconsolidated except where locally indurated by the segregation of ferruginous material derived from the glauconite. The sands composing the Monmouth deposits vary in color from reddish brown to dark green or nearly black. The fresh material always contains considerable glauconite and this gives to the deposits their dark color. In their more weathered portions the sands generally range in color from rich brown to reddish brown, but at some places they are dark gray.

¹Clark, Bull. Geol. Soc. Amer., vol. VIII, 1897, pp. 315-358.

Paleontologic Character.—The Monmouth formation is generally very fossiliferous and the forms are usually well preserved. They consist of foraminifers, pelecypods, gastropods, and cephalopods. Among the most abundant are *Exogyra costata* Say, *Gryphaea vesicularis* Lamarek, *Idonearca vulgaris* Morton, *Cardium perelongatum* Whitney, and *Belemnitella americana* Morton. They are typical Upper Cretaceous species.

Strike, Dip and Thickness.—The strike of the Monmouth formation is from northeast to southwest, and the dip is toward the southeast at the rate of about 25 feet to the mile. The maximum thickness of the Monmouth formation along its outcrop in the area of Prince George's County is from 40 to 50 feet. In northern New Jersey it is about 200 feet thick, but it steadily decreases in thickness along the strike southwestward, until it finally disappears as an outcropping formation in the north-central part of this county.

Stratigraphic Relations.—The Monmouth is conformable with the underlying Matawan and with the Rancocas, which overlies it on the Eastern Shore of Maryland and in Delaware and New Jersey. Within Prince George's County it is overlain unconformably by Eocene and Pleistocene deposits. The Monmouth is readily distinguished from the Matawan, as it lacks the darker colored micaceous sands and marls of that formation. From the Rancocas it is distinguished by the great predominance of reddish-brown sand.

THE EOCENE FORMATIONS.

THE PAMUNKEY GROUP.

The Aquia Formation.

The formation receives its name from Aquia Creek, a tributary of Potomac River in Virginia, where deposits belonging to this horizon are characteristically developed. This name was proposed by W. B. Clark¹ in 1895.

¹Clark, Johns Hopkins Univ. Circ., 1895, p. 3.



FIG. 1.—VIEW SHOWING IRREGULAR NODULES IN THE MATAWAN FORMATION NEAR PRIEST BRIDGE.

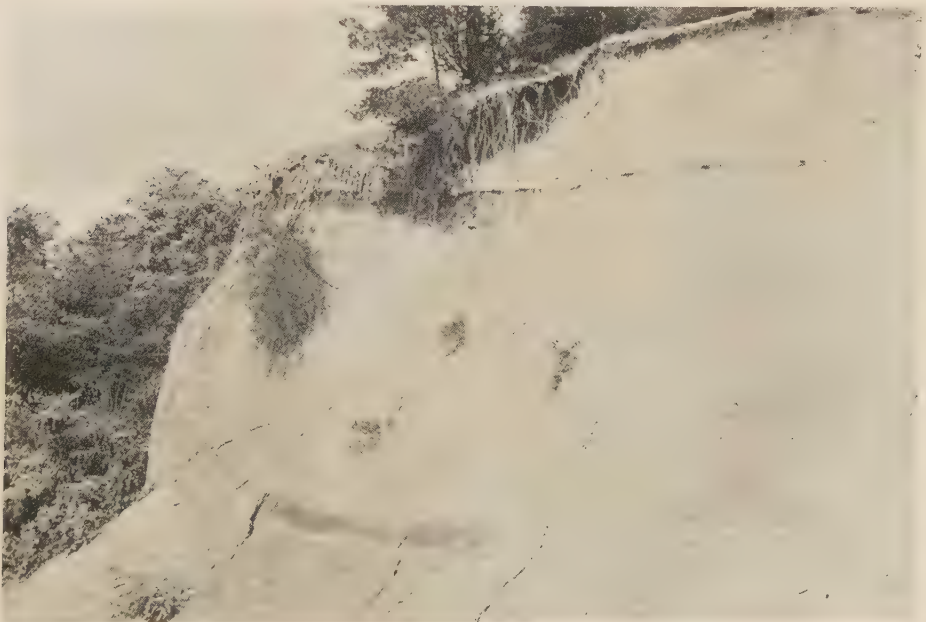


FIG. 2.—VIEW SHOWING CONTACT BETWEEN AQUIA GREENSAND AND NANJEMOY PINK CLAY AT UPPER MARLBORO.

Areal Distribution.—The Aquia is exposed throughout a broad belt 10 miles or more in width, extending from the vicinity of Collington southwestward as far as Western Branch of Patuxent River. Beyond the latter point the formation is buried beneath later deposits and outcrops only in a thin band near the headwaters of the creeks along the western margin of the county and along the Potomac River at Fort Washington. The Aquia formation dips to the southeast and is supposed to underlie the younger Eocene and Miocene beds throughout the southern portion of the area. In its wider distribution it extends from Virginia northeastward across Maryland to Delaware.

Character of Materials.—This formation consists usually of loose sand in which there is a considerable admixture of glauconite, the latter in places making up the body of the formation. Where the material is fresh it ranges in color from a light blue to a very dark green, but in regions where it has been exposed to weathering for a considerable time it has assumed a reddish-brown to light-gray color. The beds are in most places unconsolidated, although locally some have become very firmly indurated by oxide of iron. Small, well-rounded pebbles coated with iron oxide occur in a few places near the base of the formation. These gravels are typically exposed about a mile northwest of Westphalia and in numerous places about Collington. About half a mile southwest of Collington this pebble layer, which is about 2 feet in thickness, has been cemented by ferruginous material into a hard, compact rock that has been used for building purposes. Where the Aquia deposits have been exposed to the action of the atmosphere, as on the tops of divides, the iron present in the glauconite has been segregated to form bands of iron sandstone. These are very numerous and in places attain a thickness of 1 to 2 feet. Near Upper Marlboro there are a few ledges of indurated marl from which numerous species of fossils have been obtained.

This is one of the longest and best known localities for fossils in the Eocene of the Atlantic slope. The following section is exposed:

Section east of bridge at Upper Marlboro, Md.

NANJEMOY:	Feet.
Glauconitic clay.....	22
Pink clay, without glauconitic or fossils.....	22
AQUIA (Paspotansa substage):	
Coarse glauconitic sand.....	32
Shell marl with <i>Gibbula glandula</i> , <i>Fissuridea marlboroensis</i> , <i>Lucina aquiana</i> , <i>Diplodonta marlboroensis</i> , <i>Venericardia</i> <i>planicosta</i> var. <i>regia</i> , <i>Pteria limula</i> , <i>Cucullaea gigantea</i> , <i>Leda parilis</i> , <i>Nucula ovula</i>	2
Indurated ledge with <i>Turritella mortoni</i> , <i>T. humerosa</i> , <i>Mesalia obruta</i> , <i>Calyptrophorus jacksoni</i> , <i>Panopea elon-</i> <i>gata</i> , <i>Meretrix ovata</i> var. <i>pyga</i> , <i>Dosiniopsis lenticularis</i> , <i>Venericardia planicosta</i> var. <i>regia</i> , <i>Crassatellites alaeform-</i> <i>mis</i> , <i>Astarte marylandica</i> , <i>Glycymeris idoneus</i> , <i>Cucullaea</i> <i>gigantea</i> , <i>Leda parilis</i> , <i>Nucula ovula</i>	5
Glauconitic sand (known as Bryozoan sand) full of fine fragments of shells accompanied by Bryozoa, echinoid spines, and Foraminifera; and with <i>Ostrea compressiro-</i> <i>stra</i> , <i>Gryphaecostrea vomer</i> , and <i>Platidia marylandica</i>	5
	88

Paleontologic Character.—A great many fossils are to be seen in the outcrops of the Aquia along the Patuxent River and in the valley of Piscataway Creek. An idea of the variety of fossils that occur in these localities may be gained by consulting the section above. The fossils of this formation have been described and illustrated in the report on the Eocene issued by the Maryland Geological Survey.

Strike, Dip, and Thickness.—The Aquia formation is about 100 feet thick in this county and gradually thickens toward the east, beneath the later formations. It has a northeast-southwest strike and dips to the southeast at the rate of about 12½ feet to the mile.

Stratigraphic Relations.—The Aquia formation overlies the Monmouth unconformably and is overlain conformably by the Nanjemoy formation. Where the Nanjemoy has been removed by erosion it is covered by Miocene, Lafayette, or Pleistocene beds.

Subdivisions.—The Aquia formation has been subdivided into two members or substages known as Piscataway and Paspotansa, which are distinguished from each other by their contained fossils.

The Piscataway member was named from Piscataway Creek, Maryland, where it is typically developed. The member is characterized by two well-marked and rather persistent layers of indurated marls. Its thickness somewhat exceeds 50 feet. It is further characterized by a fossil fauna among which are the following forms:

Thecachampsa sericodon (?) Cope.
Synechodus clarkii Eastman.
Odontaspis elegans (Agassiz).
Otodus obliquus (Agassiz).
Pholadomya marylandica Conrad.
Gryphæa vesicularis Lamarek.
Textularia subangulata D'Orbigny.

The Paspotansa member was named from Paspotansa Creek, Virginia. It consists of a bed of greensand and greensand marl somewhat less than 50 feet thick. Among the characteristic fossils of this member are the following:

Bythocypris subæquata Ulrich.
Pleurotoma harrisi Clark.
Cancellaria graciloides Aldrich var.
Trophon sublevis Harris.
Chrysodomus engonatus (Heilprin).
Calyptrophorus jacksoni Clark.
Discosparsa varians Ulrich.
Membranipora angusta Ulrich.
Textularia gramen D'Orbigny.
Anomalina ammonoides (Reuss).

The Nanjemoy Formation.

The formation receives its name from Nanjemoy Creek, one of the tributaries of Potomac River in Maryland, in whose valley deposits belonging to this horizon are characteristically developed. This name was proposed by Clark and Martin in 1901.¹

Areal Distribution.—The Nanjemoy formation is much less extensively exposed in this county than the Aquia. It extends across the county from Hardesty to the valley of Piscataway Creek in a very circuitous and broken outcrop. In its larger relations it extends from Virginia northwestward through Maryland as far as Ches-

¹Eocene, Maryland Geol. Survey, p. 64.

peake Bay. On the Eastern Shore it does not outcrop and is so deeply buried by later deposits that it has not yet been recognized with certainty in well borings.

Character of Materials.—The Nanjemoy formation consists primarily of greensand, which is in most places highly argillaceous and locally calcareous, with certain layers carrying abundant crystals and crystalline masses of gypsum. The formation contains considerable clay, especially at its base, as shown in the section at Upper Marlboro already given. The following section is fairly typical and characteristic of the glauconite phase:

Section in ravine 1 mile south of Thrift, Md.

MIocene:	Ft.	In.
Lead-colored clay with Miocene fossils.....	40	0
EOCENE (Nanjemoy-Potapaco substage):		
Dark argillaceous greensand.....	7	0
Argillaceous greensand, packed with <i>Venericardia potapacoensis</i>	1	0
Dark glauconitic clay.....	3	0
Layer of <i>Venericardia potapacoensis</i>	0	8
Greensand with many scattered specimens of <i>Venericardia potapacoensis</i>	3	0
Line of concretions.....	0	6
Glauconitic clay with <i>Venericardia potapacoensis</i>	4	0
Dark greensand.....	5	0
Layer packed with shells of <i>Venericardia potapacoensis</i>	1	6
Argillaceous greensand.....	1	0
Line of concretions.....	0	6
Argillaceous greensand.....	3	0
Greensand with <i>Venericardia potapacoensis</i>	1	0
Dark glauconitic clay.....	3	0
Layer of shells of <i>Venericardia potapacoensis</i>	0	4
	74	6

Paleontologic Character.—A great many fossils are to be seen in the outcrops of the Nanjemoy formation along South and Patuxent rivers, along Piscataway, Mattawoman, and Nanjemoy creeks in Maryland, and along Potomac and Aquia creeks in Virginia. An idea of the abundance of these fossils may be obtained by examining the foregoing section. The fossils of the Nanjemoy formation have been described and illustrated in the report on the Eocene issued by the Maryland Geological Survey.



VIEWS SHOWING CHARACTERISTIC FOSSILS OF THE EOCENE OF PRINCE GEORGE'S COUNTY.

- FIG. 1.—TURBINOLIA ACUTICOSTATA Vaughan.
 FIG. 2.—CARPOLITHUS MARYLANDICUS Hollick.
 FIG. 3.—MERETRIX OVATA VAR PYGA Conrad.
 FIG. 4.—MODIOLUS ALABAMENSIS Aldrich.
 FIG. 5.—OSTREA COMPRESSIROSTRA Say.
 FIG. 6.—GLOBIGERINA BULLOIDES d'Orb.
 (Greatly enlarged).
 FIGS. 7, 8.—CRASSATELLITES ALAEFORMIS (Conrad).
 FIG. 9.—STREPSIDURA SUBSCALARINA Hellprin.

- FIG. 10.—CALYPTROPHORUS TRINODIFERUS Conrad var.
 FIG. 11.—CORBULA ALDRICHI Meyer.
 FIG. 12.—VENERICARDIA PLANICOSTA VAR REGIA Conrad.
 FIG. 13.—PLEUROTOMA TYSONI Clark and Martin.
 FIG. 14.—DOSINIOPSIS LENTICULARIS (Rogers).
 FIG. 15.—CUCULLAEA GIGANTEA Conrad.
 FIG. 16.—TURRITELLA MORTONI Conrad.

Strike, Dip, and Thickness.—The formation has a northeast-southwest strike and dips toward the southeast at an average rate of about $12\frac{1}{2}$ feet to the mile. The Nanjemoy is about 100 feet thick in Prince George's County and thickens gradually toward the east.

Stratigraphic Relations.—The Nanjemoy overlies the Aquia conformably, but is overlain unconformably by the Miocene, and in some places along the line of outcrop by deposits belonging to the Lafayette and the Pleistocene.

Subdivisions.—This formation, like the Aquia, is subdivided into two members or substages, known as the Potapaco and Woodstock.

The Potapaco member is so called from the early name of Port Tobacco (a corruption of the word Potapaco) Creek, one of the Maryland tributaries to Potomac River. It is characteristically clayey, especially in its lower portions. It is about 60 to 65 feet thick and carries the following characteristic fossils:

Cypræa smithi Aldrich.
Solen lisbonensis Aldrich.
(?) *Lucina astartiformis* Aldrich.
Ceiopora micropora Goldfuss.

This member is further subdivided into six zones which, together with their characteristic fossils, are fully discussed by Clark and Martin in the report already cited.¹

The Woodstock member has been named from Woodstock, an old estate situated a short distance from Mathias Point on the Virginia side of the Potomac. This member is characterized by fine homogeneous greensands and greensand marls which are less argillaceous than the underlying Potapaco beds. It ranges in thickness from 60 to 65 feet and contains certain characteristic fossils, a few of which are the following:

Pyrula penita Conrad var.
Meretrix lenis (Conrad).
Leda parva (Rogers).
Spiroplecta clarki Bagg.
Nonionina affinis Reuss.

¹Eocene, Maryland Geol. Survey, 1901, pp. 65-66.

The Woodstock member is further subdivided into two zones distinguished by characteristic fossils. These zones are described in the above-mentioned report on the Maryland Eocene, which also contains a full list of the fossils which characterize the member.

THE MIOCENE FORMATIONS.

THE CHESAPEAKE GROUP.

The Calvert Formation.

This formation receives its name from Calvert County, Md., where, in the well-known Calvert Cliffs bordering Chesapeake Bay, its typical characters are well shown.

Areal Distribution.—The Calvert is by far the most extensive formation in Prince George's County. Although it is largely covered with Lafayette and Columbia gravels, yet stream erosion has cut down to it in so many places that its distribution is very well known. It outcrops in nearly every stream-cutting throughout the southern half of the county and is represented by outliers well up on the divides over a large portion of the northern half. In its larger distribution it extends from Virginia northeastward across Maryland and Delaware into New Jersey. It has by far the most extensive development of all of the Cretaceous and Tertiary formations in this region.

Character of Materials.—The materials constituting the Calvert formation consist of blue, drab, and yellow clay, yellow to gray sand, gray to white diatomaceous earth, and calcareous marl. Between these all gradations exist. The diatomaceous earth gradually passes into fine sand by the increase of arenaceous material, or into a clay by the addition of argillaceous matter. In a similar way a sand deposit with little or no clay grades over into a deposit of clay in which the presence of sand can not be detected. Notwithstanding this variety of materials a certain sequence of deposits is commonly observed; the basal portions of the formation consist largely of diatomaceous earth, while the upper portions are composed chiefly of sand, clays, and marls. This difference in materials has led to

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a subdivision of the formation into two members, which are described below.

In a great many places, the Calvert is separated from the Eocene by a siliceous sandstone 6 to 12 inches in thickness. This ledge itself has been found to contain Miocene fossils and in places it is separated from the Eocene greensand by as much as a foot of loose sand. In Prince George's County this ledge is exposed in many places in the southeastern portion of the County, and is everywhere distinguishable from any other material present in the Miocene or Eocene. One of the best exposures of it is about $2\frac{1}{2}$ miles northwest of Nottingham along Mataponi Creek, where the following section has been taken.

Section along Mataponi Creek.

CALVERT:	Ft.	In.
Diatomaceous earth, gray in color, mixed with considerable sand in the lower portion but passing upward into a very pure variety.....	20	0
Siliceous ledge with sand grains visible on roughened weathered surface but indistinguishable in interior; vitreous cleavage; outside gray, interior black.....	0	6
Iron-stained sand with a considerable admixture of clay, arranged in thin layers suggesting shales.....	0	10
NANJEMOY:		
Coarse glauconitic sand, dark at base becoming lighter in color and more micaceous near Miocene contact.		
Exposed	6	0
	27	4

Palaeontologic Character.—The diatomaceous earth and the dark-colored clays represented in the Calvert of this county contain abundant casts of marine mollusks, almost invariably of small size. These beds also contain leaf remains.

Strike, Dip, and Thickness.—The strike of the Calvert formation is from northeast to southwest, and it dips toward the southeast at the rate of about 11 feet to the mile. The full thickness of the Calvert formation has been nowhere actually observed along the line of outcrop. The formation has been diagonally truncated by the Choptank, so that in this region it shows a maximum thickness of only about 100 feet. The Choptank and younger formations lie

above it unconformably. Fortunately, a reliable well record at Crisfield, Somerset County, exhibits the entire thickness of Miocene strata. In this well the Calvert formation is apparently about 300 feet thick. As this well is located in the extreme southern portion of the State and far down the dip, there is probably a rapid thickening of this formation as it passes to the southeast toward the ocean. At Chesapeake Beach, on the bay shore in Calvert County, a well which begins in the Calvert formation a little above tide passes out of it and into the Eocene at a depth of 60 feet; at Centerville it is found at a depth of 81 feet and is 65 feet thick; at Crisfield the formation lies 465 feet below the surface.

Stratigraphic Relations.—Near the Maryland-Delaware border the Calvert rests unconformably upon one of the Cretaceous formations (Rancocas). Farther southwest it overlies the Aquia formation, and in southern Maryland it lies unconformably upon the Nanjemoy, a relationship which shows the gradual transgression of the Miocene deposits southwestward. In this county it lies unconformably upon the Nanjemoy, Aquia, or Matawan formations and is overlain unconformably by deposits belonging to the Lafayette or Pleistocene.

Subdivisions.—The Calvert formation has been divided into two members, known as the Fairhaven diatomaceous earth and the Plum Point marls. These are more fully described in the above-mentioned report on the Miocene of Maryland.

The Fairhaven diatomaceous earth lies at the base of the formation and is characterized by the presence of a large proportion of diatoms embedded in a very finely divided quartz matrix. Calcareous material is present in this bed in only very small amounts. Besides diatoms, there are other Miocene fossils, usually in the form of casts, and organic remains reworked from the underlying Eocene beds. The name for this member is derived from Fairhaven, Anne Arundel County, where the beds are well developed.

The contact of the diatomaceous earth with the Eocene beds lies about 2 feet beneath a band of sandstone from 4 to 8 inches thick,

which carries casts of *Pecten humphreysii* and other Miocene fossils. Above this sandstone is the diatomaceous earth proper. This bed, which is about 20 feet thick, is greenish blue when fresh, but weathers to a brown or a light-buff to white color on long exposure to the atmosphere. In the extensive pits at Lyons Creek wharf in Calvert County, just across the river from this county, where the material is worked commercially, the transition from greenish blue to buff is very conspicuous.

From Fairhaven the diatomaceous beds cross southern Maryland in a northeast-southwest direction, following the line of strike, and are worked at Lyons Creek on the Patuxent, and at Popes Creek on the Potomac in Charles County. They may also be found at numerous places between these points, in cuts made by waterways. South-east of this diagonal line they gradually disappear below tide. The Fairhaven diatomaceous earth is further subdivided into three zones that are recognized by the materials and fossils which they contain.

The Plum Point marls constitute the remainder of the Calvert formation above the Fairhaven diatomaceous earth. At Plum Point, Calvert County, the beds are typically developed, and this fact has suggested the name of this member. It consists of a series of sandy clays and marls in which are embedded large numbers of organic remains, including diatoms. The color of the material is bluish green to grayish brown and buff. Fossil remains, although abundant through the entire member, are particularly numerous in two prominent beds, from 30 to 35 feet apart, in the Calvert Cliffs. These marls vary in thickness from $4\frac{1}{2}$ to 13 feet. Along Patuxent River the Plum Point marls are not exposed so extensively as in the Calvert Cliffs, but they are visible at intervals from the cliffs below Lower Marlboro southward to Ben Creek, in Calvert County. On the west bank of the river they may be seen here and there from a point opposite Lower Marlboro downstream to a point $1\frac{1}{2}$ miles below Forest Wharf, in St. Mary's County.

Along the Potomac River, the banks are usually very low and composed of Columbia sand and gravel. In consequence of this the Plum Point marls are exposed at but few places. On the Maryland side of the river they may be seen in the low cliffs at the mouth of

Chaptico Bay, in St. Mary's County, and on the Virginia side a considerable thickness of the marls is exposed along the entire length of the Nomini Cliffs. When fresh, the Plum Point marls and the Fairhaven diatomaceous earth do not differ much in appearance. The thickness of the marls increases constantly down the dip. This member is subdivided into 12 zones, which are distinguished by the lithologic character of the materials and by characteristic fossils.

The Choptank Formation.

This formation receives its name from Choptank River, Maryland, because of its great development on the northern bank of that estuary a short distance below Dover Bridge.

Areal Distribution.—The Choptank formation is confined to the southeastern portion of Prince George's County. It is exposed in the headwaters of the minor streams in the vicinity of Orme and Aquasco. In Calvert County it may be found in a long line of outcrops extending from the hilltops just west of Herring Bay to Patuxent River, but west of the Patuxent it is almost completely obscured by younger deposits. The boundaries of the Choptank formation in Calvert County are better known than in any other portion of southern Maryland, but west of the Patuxent have been determined more by calculation than by observation. They are believed, however, to be approximately correct and are fixed as accurately as present knowledge warrants. In its broader relations the formation extends from Virginia northwestward across Maryland and Delaware into New Jersey, where it has an extensive development.

Character of Materials.—The materials composing the Choptank formation are extremely variable. They consist of fine yellow quartz sand, bluish-green sandy clay, slate-colored clay, and, at some places, ledges of indurated rock. In addition to these materials, abundant fossil remains are disseminated throughout the formation. The sandy phase is characteristic of the formation in this county.

Paleontologic Character.—Although the Choptank formation is abundantly supplied with fossils, these are for the most part concen-

trated in two well-defined beds which seem to be distributed very extensively through the areas of the deposit, though not represented in Prince George's County. The fossils of this formation have recently been fully described and illustrated in the two volumes on the Miocene published by the Maryland Geological Survey.

Strike, Dip, and Thickness.—The strike of the Choptank formation is in general from northeast to southwest; but as a result of erosion, particularly on the Western Shore of Chesapeake Bay, the outcrop is very sinuous and the strike appears to change locally.

The dip does not seem to be constant throughout the extent of the formation. In Calvert County, where the Choptank is best exposed, the northern portion of the outcrop, down to Parker Creek, seems to lie almost horizontal; but farther south the formation at its base dips southward at the rate of about 10 feet to the mile, so that toward the south it occurs at lower and lower levels until in the southern portion of its area it is found in river bottoms and finally disappears beneath tide. The best place in this state to examine the dip of this formation is along the Calvert Cliffs bordering Chesapeake Bay between Parker Creek and Point of Rocks. Here an almost unbroken exposure of the Choptank may be seen dipping gradually toward the southeast.

The thickness of the Choptank formation is variable. In the well section at Crisfield, mentioned in connection with the description of the Calvert formation, the Choptank is more than 100 feet thick, so that, like the Calvert, it thickens as it passes down the dip.

Stratigraphic Relations.—The Choptank formation lies unconformably upon the Calvert formation. The unconformity is in the nature of an overlap, but is not easily discernible even where the contact is visible. The best place to observe the unconformity is in the portion of the Calvert Cliffs just below the mouth of Parker Creek. Even here it can not be seen from the beach, but is visible from a boat a short distance from the shore. This unconformity is also proved by the fact that at the above-mentioned locality the fossiliferous bed which lies lowest in the Choptank formation rests upon the Calvert, while at Mount Harmony, in Calvert County, and

farther north the upper fossiliferous bed of the Choptank rests upon the Calvert formation. How far this unconformity continues down the dip after the beds disappear from view is not known, as the data from well records are too meager to permit any conclusion to be drawn from them. Above the Choptank is the St. Mary's formation, which is not represented in this county.

Subdivisions.—The Choptank formation is subdivided into five zones, which are distinguished from one another by the character of material and the fossils they contain. These zones, together with their fossil contents, have been fully described in the State report on the Miocene of Maryland.

THE PLIOCENE (?).

The Lafayette Formation.

The name Lafayette was proposed by Hilgard in 1891¹ to replace the term Orange sand, used in Tennessee and Mississippi, and the term Appomattox, which had been applied to the deposits of the Atlantic Coast. The name is derived from Lafayette County, Miss., a region where the formation is well developed. The exact correlation of the formation has not been definitely settled, as its meager fauna has furnished little clue to its age. Its general character, firmly indurated layers, and occasional greatly decomposed pebbles suggest a formation much older than any known Pleistocene deposit of the province, and hence furnish evidence for a provisional reference to the Pliocene.

Areal Distribution.—The Lafayette forms the surface cover over the principal stream divide of the southern portion of the county. At one time, however, it probably formed a mantle over the entire area, for outliers are found north of Washington. If such was the case, the Lafayette must originally have rested upon the exposed edges of all the earlier formations represented in this region, but erosion has so reduced its area that it is now in contact principally with the Miocene, although in small areas it rests upon the Patuxent

¹Am. Geologist, vol. VIII, 1891, pp. 129-131.



FIG. 1.—VIEW SHOWING INDURATED LEDGE OF FOSSILIFEROUS MIOCENE SAND NEAR MAGRUDER FERRY.



FIG. 2.—VIEW SHOWING SURFACE OF LAFAYETTE PLAIN, NEAR CHELTENHAM.

formation and the ancient crystalline rocks. The Lafayette plain is in reality the oldest and highest of a series of five plains which were developed at successively lower levels during various epochs ranging in time from Pliocene (?) to Recent. It extends almost uninterruptedly from the District of Columbia line to the southern boundary of the county and forms one of the most striking topographic features in this area. Northeast of the District of Columbia the Lafayette is represented by a few outliers, the largest of which occurs in the vicinity of Laurel. It covers the higher portions of the divide between the Patuxent and Potomac river systems and thus becomes the most conspicuous formation of the region.

Character of Materials.—The Lafayette formation is composed of gravel, sand, and loam. These materials were so imperfectly sorted by the waves of the Lafayette sea that they are now found intermingled in varying proportions. Although there is a rough bipartite division in the deposit as a whole, the gravel occurring in greater abundance at the base and the sand and loam at the top of the formation, yet these elements are mixed together in a confusing manner. No particular kind of material is confined to any definite stratum, but all kinds may occur anywhere throughout the section. Irregular beds or lenses of loam, sand, or gravel also occur and are exposed in many places throughout the county. The gravels are considerably decayed and are usually rather small, but in the vicinity of Washington they become very coarse and are embedded in a coarse, compact sand or very stiff, clayey loam. The appearance of the gravels also changes from place to place; near Washington they are almost invariably covered with a dark-brown ferruginous coating, but farther south the amount of iron decreases considerably and the coating of iron oxide is practically absent. The heterogeneous character of the material furnishes evidence of the varied sources from which it has been obtained. Pebbles of quartz and crystalline rocks indicate the Piedmont as the source; broken iron crusts were derived from the Paleozoic formations farther west; and finally, decayed blocks of Newark sandstone are occasionally observed. While all of these various materials are present, the gravels are composed principally of quartz.

Sand forms a rather unimportant part of the Lafayette deposits. Such as is present seems to have been derived mainly from the Potomac beds. Lenses of sand occur at many places in the gravel deposits, but do not commonly form beds of great thickness or extent. The sand usually serves as the matrix for the gravels or else is intimately mixed with the loam.

Throughout the county the Lafayette is capped by a deposit of loam varying in thickness from a few inches to 10 feet or more, with an average of about 5 feet. Near Washington this loam contains considerable iron and has here and there a decided orange color. To the east and south this color becomes much less pronounced. In many places the loam resembles the loess of the upper Mississippi Valley in color and also in texture. On the broad Lafayette plain in the southern part of the county the loam shows a very pronounced mottling of drab and brick-red. This is particularly noticeable when the material is wet. It is seen in numerous road cuts, especially west of Brandywine. The Lafayette loam is in some places highly argillaceous, in others decidedly arenaceous. As a general rule, it is of very fine texture. Although the loam capping is relatively free from bands of gravel, they are not entirely absent. Single pebbles are not uncommon in the loam and locally there are well-defined beds of gravel and sand. The following section, taken $1\frac{1}{2}$ miles southeast of Piscataway, makes these relations clearer:

Section $1\frac{1}{2}$ miles southeast of Piscataway.

LAFAYETTE:	Feet.
Fine grayish-yellow loam.....	5
Medium-coarse gravel in a matrix of gray sand.....	4
Yellow cross-bedded sand.....	3
Unassorted gravel mixed with gray sand.....	5
	17

Physiographic Expression.—As described under “Topographic features,” the deposits of this formation form a plain of deposition which is well-developed in many places in the Coastal Plain and slopes gradually toward the sea. In the vicinity of Anacostia the base of the Lafayette plain is at a height of 280 feet and its surface at 300 feet. At Charlotte Hall in St. Mary’s County, 30 miles to the south, the base is not visible, but the surface lies at

an altitude of about 200 feet. This shows, therefore, a difference of 100 feet in 30 miles, or a surface slope toward the sea of about 3 feet to the mile. So slight and gradual a decline in elevation might be attributed to the original attitude of the material when it was deposited were it not for the fact that the Sunderland terrace, which wraps about the base of the Lafayette, has suffered a deformation of 20 feet, or about 8 inches to the mile, throughout the same region, and the Wicomico appears also to have been affected by a slight tilting. It is probable, therefore, that the present slope of the Lafayette formation is due partly to its original attitude and partly to subsequent tilting.

Paleontologic Character.—Fossils are practically lacking in the Lafayette deposits of the Atlantic Coast region none being found in this area. Pebbles containing Paleozoic fossils are present in the formation at many places throughout the district, but are of importance only because they show the source of the materials.

Thickness.—The thickness of the Lafayette is somewhat variable. In its northwesternmost exposures the formation shows a thickness of 3 to 10 feet, the amount increasing somewhat toward the southeast. Over the broad plain in the vicinity of Brandywine the Calvert, which is the next subjacent formation, is reached at a depth of about 28 feet. The maximum thickness of the Lafayette in this county probably does not exceed 40 feet.

Stratigraphic Relations.—A very marked unconformity separates the Lafayette from all underlying formations. In one place or another within the Coastal Plain province it overlies almost every older formation represented in the region, and thin remnants are present in many places on the eastern borders of the Piedmont Plateau. In Prince George's County it rests mostly upon the Calvert and Choptank formations and is, in the main, a surface deposit, although locally it in all probability dips beneath beds of Pleistocene age.

THE PLEISTOCENE FORMATIONS.

THE COLUMBIA GROUP.

The Pleistocene formations of the Atlantic Coastal Plain are united under the name Columbia group. They have many characteristics in common, owing to their similar origin. They consist of gravel, sands, and loam which are stratigraphically younger than the Lafayette formation. The Columbia group in this area comprises three formations, the Sunderland, Wicomico, and Talbot. They appear as the facings of different plains or terraces, possessing very definite physiographic relations (see fig. 2), as described under the heading "Topographic features."

On purely lithologic grounds it is impossible to separate the three formations composing the Columbia group. The materials of all have been derived mainly from the older formations which occur in the immediate vicinity, but include more or less foreign material brought in by streams from the Piedmont Plateau or from the Appalachian region beyond. The deposits of each of these formations are extremely varied, their general character changing with that of the underlying formations. Thus deposits belonging to the same formation may, in different regions, differ far more lithologically than deposits of two different formations lying in proximity to each other and to the common source of most of their material. Cartographic distinctions based on lithologic differences could not fail to result in hopeless confusion. At some places the older Pleistocene deposits are more indurated and their pebbles more decomposed than those of the younger formations, but these differences can not be used as criteria for separating the formations, inasmuch as loose and indurated, fresh and decomposed materials occur in each of them.

The fossils found in the Pleistocene are far too meager to be of much service in separating the deposits into distinct formations, even though essential differences between some of them may exist. It is the exceptional and not the normal development of the formations that has rendered the preservation of fossils possible. These consist principally of fossil plants that were preserved in bogs, but in a few

places about Chesapeake Bay local Pleistocene deposits contain great numbers of marine and estuarine mollusks.

At almost every place where good sections of Pleistocene materials are exposed the deposit from base to top seems to be a unit. At some places, however, certain layers or beds are sharply separated from the underlying beds by irregular lines of unconformity. Some of these breaks disappear within short distances, showing clearly that they are only local phenomena in the same formation, the result of contemporaneous erosion by shifting shallow-water currents. Whether all these breaks would thus disappear if sufficient exposures occurred to permit the determination of their true nature is not known. An additional fact which indicates the contemporaneous erosive origin of these unconformities is that in closely adjoining regions they seem to have no relation to one another. Inasmuch as the Pleistocene formations lie in a nearly horizontal plane it would be possible to connect these separation lines if they were subaerial unconformities due to an interval of erosion. In the absence of any definite evidence that these lines are stratigraphic breaks separating two formations, they have been disregarded. Yet it is not improbable that in some places the waves of the advancing sea in Sunderland, Wicomico, and Talbot time did not entirely remove the beds of each preceding period of deposition over the area covered by the sea in its next transgression. Especially would materials laid down in depressions be likely to persist as isolated remnants which later were covered by the next mantle of Pleistocene deposits. If this is the case each formation from the Lafayette to the Wicomico is probably represented by fragmentary deposits beneath the later Pleistocene formations. Thus in certain sections the lower portions may represent an earlier period of deposition than that of the overlying beds. In regions where pre-Quaternary materials are not exposed at the bases of the escarpments each Pleistocene formation near its inner margin probably rests upon the attenuated edge of the next younger formation. Inasmuch as lithologic differences afford insufficient criteria for separating these late deposits, and as sections are not numerous enough to furnish distinctions between local interformational unconformities and widespread unconformities result-

ing from an erosion interval, the whole mantle of Pleistocene materials occurring at any one locality is referred to the same formation. The Sunderland is described as overlying the Cretaceous, and Tertiary deposits and as extending from the base of the Lafayette-Sunderland escarpment to the base of the Sunderland-Wicomico escarpment. The few deposits of Lafayette materials which may possibly underlie the Sunderland are disregarded because they are unrecognizable. Similarly the Wicomico is described as including all the gravels, sands, and clays overlying the pre-Lafayette deposits and extending from the base of the Sunderland-Wicomico escarpment to the base of the Wicomico-Talbot escarpment. Perhaps, however, materials of Lafayette and of Sunderland age may underlie the Wicomico in places. In like manner the Talbot may here and there rest upon deposits of the Lafayette, Sunderland, and Wicomico.

The Sunderland Formation.

This formation has been named from the little village of Sunderland, Calvert County, near which it is typically developed. The name was first applied to the formation by G. B. Shattuck in May, 1901.¹ The Sunderland corresponds approximately with the Earlier Columbia of McGee and with parts of the Bridgeton and Pensauken of Salisbury. Its Pleistocene age is indicated by the modern appearance of its plant remains and by its relation to the next younger formation, the Wicomico, in which boulders bearing glacial striæ have been found.

Areal Distribution.—The Sunderland formation is developed as a terrace or plain which occupies the tops of the secondary stream divides below the Lafayette formation, between the Patuxent and Potomac rivers. Since its deposition it has suffered more erosion than either of the two younger formations, but enough of it still remains within the area to make its mapping possible and to establish its relations to the other deposits. The surface of the Sunderland plain varies in altitude from 200 feet in the northern and central

¹Johns Hopkins Univ. Circ. No. 152.

portions of the county to 180 feet in the southern portion. Throughout this tract the original surface of the formation was nearly level, but the streams which now flow across it have locally produced a gently rolling surface. In the vicinity of Laurel there are many gravels present in the surface soils that may belong to this formation though not so represented on the map. The Potomac strata in that locality contain gravel bands, and it seems more probable that the surficial gravels are the residual materials of these Cretaceous beds or of the Lafayette formation that occurs in the immediate vicinity.

Character of Materials.—The materials which compose the Sunderland formation consist of clay, sand, gravel, and ice-borne boulders. As explained above, these materials as a rule do not lie in well-defined beds, but grade into each other both vertically and horizontally. The coarser materials, with the exception of the ice-borne boulders, have in the main a cross-bedded structure, but the clays and finer material are either developed in lenses or horizontally stratified. The erratic ice-borne blocks are scattered through the formation and may occur in the gravel, sand, or loam. The coarser material throughout the formation tends to occupy the lower portions and the finer the upper portions, but the transition from one to the other is not marked by an abrupt change, and at many places the coarse materials are present above and the finer materials below. As a whole the material is coarser on the western side of the County, in the Potomac basin, than elsewhere. In the vicinity of Congress Heights, the gravels of the Sunderland are rather commonly cemented by ferruginous material. The ferruginous conglomerate used in the wall about the grounds of St. Elizabeth's Asylum was obtained from beds of consolidated Sunderland deposits. Many of the pebbles of the Sunderland are much decayed, but in general they show less decomposition than the Lafayette gravels.

Physiographic Expression.—The Sunderland deposits occupy and form the Sunderland plain mentioned in the discussion of topography (p. 80). This plain is separated from the Lafayette terrace by a well-defined scarp. This scarp has suffered considerable modification since its formation, and where it was not prominent it has

been transformed to a gently rolling surface or has been lost altogether. At Charlotte Hall, a short distance beyond the southern margin of the county, this scarp is preserved in nearly its original sharpness. It is also visible south of Bryantown in Charles County and north of Aquasco. In all these localities the original scarp was low, not exceeding 20 feet in height, but at Congress Heights, south of Anacostia River, the scarp separating the Lafayette and Sunderland surfaces is over 60 feet high and is the finest and best defined of all the ancient escarpments of this portion of the Coastal Plain. At Congress Heights the surface of the Lafayette plain lies at an altitude of about 260 feet. From this height a steep slope descends, cutting through the Lafayette and underlying Miocene beds, to the 200-foot contour, where the broad Sunderland plain abuts against the scarp and slopes gently away from it. The Sunderland formation is also usually separated from the Wicomico formation by a well-pronounced scarp; this is discussed in the section following, which is devoted to the Wicomico.

As already stated, the Sunderland plain stands at a height of 200 feet near Anacostia and of 180 feet at Charlotte Hall, 30 miles to the southeast. The surface of this plain thus slopes southeastward at the rate of 8 inches to the mile. It also slopes gently toward the larger estuaries.

Paleontologic Character.—No fossils have been discovered in the deposits of Sunderland age in Prince George's County, though plant remains have been found at several places in the State. A few miles to the east of the Patuxent River a typical Sunderland plant bed is exposed along the Chesapeake Beach Railroad in the extreme southwest corner of Anne Arundel County between Wilson and Owings Station. At this place a plant bed occurs at the base of the deposit. It consists of a stratum of black clay about 3 feet in thickness, in which are numerous small lignitized stems.

Thickness.—Although the materials of the Sunderland lie at varying elevations above sea level in Prince George's County, the thickness of the formation is not great at any point. That the deposits were laid down on a sloping and dissected plain is proved by many

well records and observations which show that the surface of the underlying formations rises in passing from the stream valleys to the divides. Consequently, the thickness of the Sunderland can not be determined by the elevation of the deposits, but the evidence furnished by the excavations and well records on the stream divides shows that the formation probably has an average thickness of about 35 feet.

Stratigraphic Relations.—Throughout the Coastal Plain the Sunderland overlies unconformably various formations of Cretaceous, and Tertiary age. In Prince George's County it lies unconformably upon the Aquia, Nanjemoy, Calvert, and Choptank formations. It is not improbable that the edges of the Lafayette formation extend beneath part of the Sunderland deposits, although this can not be determined because of the absence of any definite line denoting a stratigraphic break and because of the similarity of the materials of the two formations.

The Wicomico Formation.

This formation receives its name from Wicomico River, in southern Maryland. The name was proposed by G. B. Shattuck in May, 1901.¹ The Wicomico represents the upper part of the Later Columbia of McGee and Darton and a part of the Pensauken of Salisbury. The presence of ice-borne boulders furnishes evidence for its contemporaneity with the ice invasion, although the particular drift sheet with which the formation should be correlated has not yet been determined.

Areal Distribution.—The next younger formation of Pleistocene age is the Wicomico. Like the Sunderland, it was deposited on a terrace or plain. It lies topographically lower than the Sunderland, wraps around it like a border, and extends up the principal stream estuaries which penetrate it. In Prince George's County the Wicomico formation is distributed in the stream valleys through the entire area, and is especially well developed in the basin of Patuxent River.

¹Johns Hopkins Univ. Circ. No. 152.

Character of Materials.—The materials which constitute the Wicomico formation are similar to those found in the Sunderland—in fact, many of them have been derived from that formation. They consist of clay, peat, sand, gravel, and ice-borne boulders. The distribution of these materials is similar to that of those in the Sunderland in that they grade one into another both vertically and horizontally, the coarser materials preponderating at the base of the formation and the finer materials toward the top. At some places the materials are very much decayed, as in the Sunderland.

In the Potomac Valley near Washington boulders carrying glacial striæ have been found in the Wicomico formation. The great size of these boulders and their occurrence with much finer materials furnish evidence of their transportation by floating ice.

The amount of loam present in the Wicomico is exceedingly variable. Wherever the loam cap is well developed the roads are very firm and the land is suitable for the production of grass and grain; but where the loam is present in small quantities or absent altogether the roads are apt to be sandy.

Physiographic Expression.—The Wicomico formation is developed in a terrace which is described in the section headed "Topographic features" as the Wicomico plain. This plain is separated from the Sunderland terrace, which lies above it, by a scarp, usually above 20 feet in height, which is one of the most constant and striking topographic features in the region. The Wicomico plain is in turn in most places separated by an escarpment from the Talbot terrace, which wraps around it at a lower elevation. From the Sunderland-Wicomico escarpment the surface of the Wicomico formation slopes away gently toward the surrounding waters in the manner of a wave-built terrace. In the northern portion of the county the surface of the Wicomico, at the base of this escarpment, lies at an elevation of about 100 feet, while in the southern portion the elevation of the corresponding surface is about 90 or 95 feet, indicating a very gentle slope toward the southeast. Since the Wicomico was deposited it has been subjected to considerable erosion and its originally level surface has been transformed, at least along the waterways, into a gently rolling one.

Paleontologic Character.—No good Wicomico fossil localities are known in Prince George's County, but in Anne Arundel County, about one mile southeast of Queen Anne (Hardesty), there is a peat bed within and just at the base of the formation. Here, at an elevation of 30 feet above the stream, there is a deposit of carbonaceous material about 20 feet thick. About $1\frac{1}{2}$ feet of this is composed principally of peat. The leaf impressions are mainly of grasses and stems, but some insect remains and beetle-wing covers are also present. Some years ago a tooth of *Elephas Americanus* DeKay was found in Wicomico materials in the pits of the Washington Brick Company located in the northeastern portion of Washington, in the area bounded by Florida and Trinidad avenues and the Bladensburg turnpike. The tooth was obtained at a depth of 35 feet from the surface.

Thickness.—The thickness of the Wicomico formation is not at all uniform, owing to the uneven surface upon which it was deposited. It ranges from a few feet to 50 feet or more. The formation dips into the valleys and rises on the divides, so that its thickness is not so great as might be supposed from the fact that the base is in many places as low as 40 feet while the surface rises locally to 100 feet above sea level. Notwithstanding these irregularities the formation as a whole occupies an approximately horizontal position, with a slight southeasterly dip. The average thickness of the formation in this county is about 20 feet.

Stratigraphic Relations.—In this region the Wicomico overlies unconformably the granite-gneiss and the various formations of Cretaceous and Tertiary age. It is in many places in contact with the Sunderland on the one hand and with the Talbot on the other. It is probable that the Sunderland formation extends locally somewhat below the Sunderland-Wicomico scarp and may run out beneath and underlie the edge of the Wicomico formation where the two are in contact. In such places this contact between the Wicomico and Sunderland would be an unconformity.

The Talbot Formation.

Talbot County, Md., where the formation occupies a broad terrace bordering numerous estuaries, has furnished the name for this formation. It was first given by G. B. Shattuck in 1901.¹ The Talbot represents the lower part of the Later Columbia described by McGee and Darton and corresponds approximately to the Cape May formation of Salisbury. Its Pleistocene age is proved by the fossils found at Cornfield Harbor.

Areal Distribution.—The Talbot formation is well developed in Prince George's County. It occurs as a terrace of varying width extending from the Wicomico-Talbot scarp out to the edge of the surrounding waters. It is well distributed throughout the region, bordering the various estuaries and streams. Its most continuous and unbroken areas are situated in the valleys of the Patuxent and Anacostia rivers.

Character of Materials.—The materials which compose the Talbot formation consist of clay, peat, sand, gravel, and ice-borne boulders. As in the Sunderland and Wicomico deposits, these materials grade into each other both vertically and horizontally, and the formation exhibits the same tendency toward a bipartite division, with the coarser materials beneath and the finer materials above. There is, on the whole, much less decayed material in the Talbot than in the two preceding formations and as a result the formation has a much younger appearance than the other Pleistocene deposits.

In the western portion of the county, in the vicinity of Washington and Anacostia, the Talbot beds contain many large boulders which have been carried by ice and dropped in deposits of much finer material. Some of these boulders show their glacial origin in that they have been planed by the wearing action of the ice and bear glacial striae. Cross stratification is very common in the Talbot deposits. One of the best exposures of this structure can be seen in a shallow cut along the Chesapeake Beach Railroad about one-fourth mile from Patuxent River. Another good exposure of cross stratifi-

¹ Johns Hopkins Univ. Circ. No. 152.



FIG. 1.—VIEW SHOWING THE DISSECTED SURFACE OF THE SUNDERLAND PLAIN, IN THE VICINITY OF THE PATUXENT RIVER.



FIG. 2.—VIEW SHOWING MATERIALS OF THE TALBOT FORMATION OVERLYING EOCENE GREENSAND, NEAR PISCATAWAY.

cation in the Talbot occurs just north of Lyons Creek, in Anne Arundel County. The following section was taken on the banks of Anacostia River, near Washington:

*Section on west side of Anacostia River south of Pennsylvania avenue,
Washington, D. C.*

TALBOT:

	Ft.	In.
Sandy loam, light yellow to brown in color.....	3	6
Fine yellow sand with here and there isolated pebbles or thin lenses of gravel 4 to 6 inches thick; gravel up to 6 inches in diameter.....	7	0
Mass of gravel of all sizes, unstratified, some several feet in diameter; yellow sandy matrix; striæ on gravels; materials generally fresh in appearance; a few small lenses of yellow sand free from gravel. In places iron crusts have formed in the sand and gravel, cementing them together. Amount exposed..	11	0
	21	6

Physiographic Expression.—The Talbot formation is developed as a terrace capping, forming the Talbot plain described under the heading “Topographic features.” It wraps around the lower margin of the Wicomico terrace, from which it is separated in most places by a low escarpment. From the base of the Wicomico-Talbot scarp, which is at an elevation of 40 to 45 feet, the surface of the Talbot formation slopes gently toward the surrounding waters. This surface has chiefly, if not entirely, the initial slope which was imparted to it during its period of deposition. Usually this terrace is terminated by a low scarp cut by the waves of Chesapeake Bay or its estuaries, but locally it slopes gently to the water’s edge. The Talbot formation has suffered less erosion than either the Sunderland or the Wicomico. It has been elevated above the water for so short a time that such streams as have found their way across its surface have not been able to change materially its original level character.

Paleontologic Character.—In the Maryland portion of the Coastal Plain there are a number of localities at which fossil remains of either plants or animals or both occur in the Talbot deposits. The only specimen of animal remains found in the Talbot deposits of Prince George’s County consist of a bone of a mammoth determined by J. W. Gidley as the right humerus. It was found about $2\frac{1}{4}$ miles

northwest of Upper Marlboro at the road crossing of Cabin Branch near the Western Branch of the Patuxent River. It is now preserved in the museum of Georgetown University. Near Cornfield Harbor, at the mouth of Potomac River, the formation has yielded a great number of molluscan shells representing a varied fauna of marine and brackish-water origin. Practically all the plants and animals are forms which still exist in this or other regions.

Thickness.—The thickness of the Talbot formation is extremely variable, ranging from a few feet to 40 feet or more. The unevenness of the surface upon which it was deposited has in part caused this variability. The proximity of certain regions to the mouths of streams during the Talbot submergence also accounts for the increased thickness of the formation in such areas.

Stratigraphic Relations.—The Talbot rests unconformably, in different portions of the region, upon various older formations belonging to the Cretaceous or Tertiary systems. It may in places rest upon deposits of Lafayette, Sunderland, or Wicomico age, although no positive evidence has yet been found to indicate such relations to the older Pleistocene formations. The deposits occupy a nearly horizontal position, having only a slight slope toward Chesapeake Bay and its estuaries.

THE RECENT DEPOSITS.

In addition to the four terraces already discussed, a fifth is now being formed by the waters of the rivers and the waves of the estuaries. This terrace is everywhere present along the water's edge, extending from a few feet above tide to a few feet below. It is the youngest and topographically the lowest of the series. Normally it lies beneath and wraps about the margin of the Talbot terrace, from which it is separated by a low scarp that as a rule does not exceed 15 to 20 feet in height. Where the Talbot formation is absent, the Recent terrace may be found at the base of either of the other three terraces. In such places, however, the scarp which separates them is higher in proportion as the upper terrace is older. Peat, clay,

sand, and gravel make up the formation and these materials are deposited in deltas, flood plains, beaches, bogs, dunes, bars, spits, and wave-built terraces.

INTERPRETATION OF THE GEOLOGICAL RECORD.

Almost all the formations which occur within Prince George's County have a much more extensive development in the regions beyond its borders. If study were confined to the area of this county alone many of the conclusions drawn from such investigations might be unsatisfactory and erroneous. The geologic history of the county, which is here outlined, has been based on work done not only in this area but also throughout the North Atlantic Coastal Plain from Raritan Bay to Potomac River and in certain localities in Virginia and the Carolinas.

A study of the geologic history of the county shows that it has been long and complicated. This is indicated by the many different kinds of strata represented and by the relations which they bear to one another. There are deposits that were formed in fresh or brackish water; others that show evidence of their deposition in marine waters, some in water of shallow depth, others in deep water; while breaks in the conformity of the different strata indicate that from the time of the formation of the earliest beds down to the present day the region has undergone many elevations and subsidences.

SEDIMENTARY RECORD OF THE CRYSTALLINE ROCKS.

In this section rocks older than the Cretaceous are present only in the Piedmont Plateau. It is exceedingly difficult to interpret the past history of the Piedmont region for the reason that the whole area has been subjected to many great changes which have essentially modified the original materials; yet the studies of Williams, Keith, Mathews, Bascom, and others have revealed many facts concerning the original condition of the rocks now occupying this region. Nearly all the rocks of the Piedmont are metamorphic in character. Many of these rocks were originally sedimentary deposits, but in the processes of metamorphism have now lost nearly all traces of their

original character. Consequently it is scarcely possible to explain the conditions under which they were originally deposited. Yet it may be said that a large portion of the area which the Piedmont metamorphic rocks now occupy was under water at one time, or perhaps many times, and received in some places deposits of sand and mud carried in by streams, while in other places beds of limestone were formed. It is not known how long this sedimentation continued or how many breaks took place between successive periods of deposition. It has been thought by most recent workers in the Piedmont region that the rocks there include not only representatives of the Archean, to which most of the earlier geologists referred them, but of the Cambrian and Ordovician as well. These old rocks have been broken through in many different places by sheets and dikes of igneous material. Thus the Piedmont metamorphics comprise representatives of both igneous and sedimentary rocks. The structure of these rocks when first formed was undoubtedly much more simple than at present, but they have been repeatedly subjected to various processes of metamorphism by which the beds have been folded and crumpled and the original mineral composition has been greatly changed.

There is no evidence to show a submergence of this area during the latter part of the Paleozoic era nor during the Triassic period. It probably remained as a land mass during most of this time, furnishing terrigenous materials to the Paleozoic sea to the west and to the Atlantic Ocean far to the east. It is of course possible that it may have been depressed beneath the ocean waters and covered with sediments many times, but, if so, later erosion has removed such deposits from the crystalline surface.

SEDIMENTARY RECORD OF THE LOWER CRETACEOUS.

The earliest of the known unconsolidated deposits lying upon the floor of crystalline rocks belong to the Patuxent formation of the Potomac group. It indicates a submergence of the Coastal Plain in this region of sufficient extent to cover the whole area with shallow water. The cross-bedded sands and gravels furnish evidence of shift-

ing currents, as do also the abrupt changes in the character of the materials, both horizontally and vertically. The presence of numerous land plants in the clays shows the proximity of the land.

The deposition of the Patuxent formation was ended by an uplift or warping in which many of the stream valleys were occupied for a portion of their courses by bogs and swamps of the Arundel formation. In these marshes there was an extensive development of plant life and in them also were deposited iron ores that are now of considerable value. After an uplift and interval of erosion the land was again depressed beneath sea level. Physical conditions similar to those which had prevailed during Patuxent time existed during this period of submergence, in which the Patapsco formation was laid down. Dicotyledonous plants, which are very rare and primitive in structure in the Patuxent deposits, are abundant in the Patapsco and belong to higher types. This seems to indicate that a long time intervened between the two periods of deposition, during which the land flora of the region materially changed. After the deposition of the Patapsco formation the region again became land through an upward movement which drained all the previously existing estuaries and marshes. Erosion at once became active and the Patapsco surface was dissected.

SEDIMENTARY RECORD OF THE UPPER CRETACEOUS.

A downward land movement again submerged the greater portion of the region, leaving only a very narrow strip of Patapsco deposits above water. The Raritan formation was next deposited, under conditions very similar to those which had existed during the previous submergence. Raritan deposition was terminated by an uplift which again converted the entire region into land.

The widespread development of shallow-water deposits, everywhere cross-bedded and extremely variable in lithologic character, and the presence throughout these deposits of land plants furnish some evidence that sedimentation took place not in open ocean waters but in brackish or fresh-water estuaries and marshes that were indirectly connected with the ocean, which may have at times locally

broken into the area. Some land barrier to the east of the present shore line probably existed and produced these conditions, but its position and extent can not be determined.

The period during which the Magothy deposits were formed was one of transition from the estuarine or fresh-water conditions of Patapsco and Raritan time to the marine conditions under which the Matawan and Monmouth were laid down. The great variability in the lithologic character of the materials, the coarseness of the sands and gravels, and the cross-bedding all suggest conditions similar to those of the preceding periods. On the other hand, the local pockets of glauconitic sand and the presence of marine invertebrates suggest the marine conditions of the late Cretaceous. The probability is that over most of the area where Magothy deposits are now present Potomac conditions prevailed during the greater part of the period and in some places perhaps during the whole of it, but that occasionally, through the breaking down of the land barriers which had kept out the ocean, there were incursions of sea water, bringing in marine forms of life.

At the close of Magothy time the region was uplifted and a period of erosion was inaugurated. During this erosion interval comparatively small amounts of material were removed. In some places it is impossible to establish definitely any stratigraphic break between the Magothy and the Matawan. This may be because the erosion interval was comparatively short or because the elevation of the land above the water was so slight that it did not permit the streams to cut channels in the recently formed deposits.

Not until late Cretaceous time did a downward movement occur of sufficient extent to permit the ocean waters to transgress widely over this region. During the Matawan and Monmouth epochs probably all of the county was beneath the ocean. The streams from the low-lying land evidently carried into the ocean at this time only small amounts of fine sand and mud, which afforded conditions favorable to the production of glauconite and permitted the accumulation of the greensand beds that are so characteristic of the Upper Cretaceous deposits along the Atlantic Coast. During this time very slight changes took place along the continental border, although

elevation was probably proceeding slowly, as the Matawan and Monmouth formations are found outcropping farther and farther to the southeast.

After the deposition of the Monmouth formation land movements again caused the shore line to retreat eastward, but to what point is not definitely known. Farther north, in New Jersey, deposition still continued in some places, for the Rancocas formation, which overlies the Monmouth formation and is not recognizable in the Maryland area, is there overlain by another and later deposit of Cretaceous age, the Manasquan formation.

SEDIMENTARY RECORD OF THE EOCENE.

At the close of the Cretaceous period the recently deposited sediments were uplifted to form a land mass and sedimentation was succeeded by erosion. In early Tertiary time a depression carried most of the region again beneath the waters of the ocean and the Eocene deposits were formed. The great amount of glauconite present in these formations indicates that the adjacent land mass must have been low and flat, so that the streams carried only small amounts of terrigenous material. The water in which this was dropped was doubtless only a few hundred fathoms deep, as glauconite is not produced at great depths. The land-derived materials at the beginning of the Eocene consisted of small, well-rounded pebbles which were deposited in several places in the region; but later the materials carried consisted of fine sand or clay. Many forms of animal life existed in these waters and their remains now compose layers of marl several feet in thickness.

Studies of the fossils found in the Eocene deposits indicate that there were many changes in the fauna during this time. These changes were probably influenced to a greater or less extent by variations in physical environment, yet the character of the deposits themselves gives little evidence of such changes. Instead it seems that the conditions under which the Eocene deposits were produced were remarkably uniform, considering the great length of time which elapsed from the beginning to the close of the period.

SEDIMENTARY RECORD OF THE MIOCENE.

Eocene sedimentation was brought to a close by an uplift by which the shore line was carried far to the east and probably all of the present State of Maryland became land. This was followed by a resubmergence and another cycle was commenced. The deposits of the Miocene were laid down upon the land surface which had just been depressed beneath the water. Sluggish streams brought in fine sand and mud, which the waves and ocean currents spread over the sea bottom.

Near the beginning of Miocene submergence, certain portions of the sea bottom received little or no materials from the land, and the water in those places was well suited as a habitat for diatoms. These must have lived in the waters in countless millions, and as they died their silicious shells fell to the bottom and produced the beds of diatomaceous or infusorial earth which are so common in the lower part of the Calvert formation. Many Protózoa as well as Mollusca lived in the same waters and their remains are plentifully distributed throughout the deposits. During the Miocene epoch the conditions seem to have been favorable for animal life, as may be inferred from the great deposits of shell marl which were then formed.

After the deposition of the Calvert formation the region was again raised and subjected to erosion for a short period, and then sank once more beneath the sea. The Choptank formation was laid down contemporaneously with the advancing ocean. This formation lies unconformably upon the Calvert, and farther north transgresses it. In neighboring regions to the south of this county a third Miocene formation, the St. Mary's, was deposited conformably upon the Choptank at a later period.

SEDIMENTARY RECORD OF THE LAFAYETTE FORMATION.

At the close of the Miocene the entire region was uplifted to form land. Streams at once began to carve valleys on the featureless surface. These conditions continued until the country was reduced approximately to a base-level, so that the weathered products of the Piedmont were not carried off by the sluggish streams. Then a sub-

sidence occurred which again brought the region under water. Coincident with the subsidence there seems to have been a slight elevation and tilting of the region west of the shore line. The heads of the streams were given renewed force, enabling them to carry down and spread over this region large quantities of gravel and sand, derived from the Piedmont and Paleozoic formations to the west.

The evidence for the source of the material is found in many different pebbles whose origin can be traced by their lithologic character or the fossils they contain. In the vicinity of Washington many of the gravel deposits contain fossils of Devonian and Carboniferous age brought from regions beyond the Blue Ridge. These fossils show that Potomac River had extended its drainage basin westward to those regions. During the submergence beneath the Lafayette sea, conditions were not uniform over the entire area, as gravel deposits were forming in some places at the same time that the clay beds were being deposited in others adjoining. Yet on the whole sedimentation was remarkably uniform throughout the area, considering the circumstances under which it took place. Over the former land surface a fairly persistent capping of gravel was deposited. But land movements were again taking place slowly. The velocity of the streams was checked so that gravel could no longer be carried down except in occasional freshets. Fine sand and loam were laid down over the gravel which had been previously deposited. This loam, which is so extensively developed over a large portion of Prince George's County, marks the last period of Lafayette sedimentation. It marks also the last time that the entire region was submerged beneath the ocean waters.

SEDIMENTARY RECORD OF THE PLEISTOCENE.

At the close of the Pliocene epoch the region was raised again and extensively eroded, and was then lowered and received the deposits which constitute the first member of the Columbia group. The Sunderland, Wicomico, and Talbot formations, which make up this group, are exposed as a series of terraces lying one above the other throughout the North Atlantic Coastal Plain from Raritan

Bay to Potomac River, as well as in Virginia and probably still farther south. The key to the solution of the relations existing between the surficial deposits of Maryland lies almost exclusively in a correct correlation of these terraces. Much light may be thrown on this problem by a careful study of the Recent terrace now forming along the shores of the Atlantic Ocean and Chesapeake Bay and its tributaries. A discussion of this terrace is given below.

After the close of the post-Lafayette erosion period the Coastal Plain was gradually lowered and the Sunderland sea advanced over the sinking region. The waves of this sea cut a scarp against the existing headlands of Lafayette and older rocks. This scarp was prominent in some places and obscure in others, but may be readily recognized in certain localities. As fast as the waves supplied the material, the shore and bottom currents swept it out to deeper water and deposited it so that the basal member of the Sunderland formation, a mixture of clay, sand, and gravel, represents the work of shore currents along the advancing margin of the Sunderland sea; whereas the upper member, consisting of clay and loam, was deposited by quieter currents in deeper water after the shore line had advanced some distance westward and only the finer material found its way very far out. Ice-borne boulders are also scattered through the formation at all horizons.

After the deposition of the Sunderland formation, the country was again elevated above ocean level and erosion began to tear away the Sunderland terrace. This elevation, however, was not of long duration and the country eventually sank below the waves again. At this time the Wicomico sea repeated the work which had been done by the Sunderland sea except that it deposited its materials at a lower level and cut its scarp in the Sunderland formation. At this time also there was a contribution of ice-borne boulders which were deposited promiscuously over the bottom of the Wicomico sea. These are now found at many places embedded in the finer material of the Wicomico formation.

At the close of Wicomico time the country was again elevated and eroded, and then lowered to receive the deposits of the Talbot sea. The geologic activities of Talbot time were a repetition of those car-

ried on during Sunderland and Wicomico time. The Talbot sea cut its scarp in the Wicomico formation, or in some places removed the Wicomico completely and cut into the Sunderland or still older deposits. Deposits were made on its terrace, a flat bench at the base of this escarpment. Ice-borne boulders are also extremely common in the Talbot formation, showing that blocks of ice charged with detritus from the land drifted out and deposited their load over the bottom of the Talbot sea.

Embedded in the Talbot formation at many places there are lenses of drab-colored clay with plant remains. The stratigraphic relations of the lenses of clay occurring in the Coastal Plain show that they are invariably unconformable with the underlying formation and apparently so with the overlying sand and loams belonging to the Talbot. This relationship was very puzzling until it appeared that the apparent unconformity with the Talbot, although in a sense real, does not, however, represent an appreciable lapse of time and that, consequently, the clay lenses are actually a part of that formation. In brief, the clays carrying plant remains are regarded as lagoon deposits made in ponded stream channels and gradually buried beneath the advancing beach of the Talbot sea. The clays carrying marine and brackish-water organisms are believed to have been at first off-shore deposits made in moderately deep water, and later brackish-water deposits, formed behind a barrier beach and gradually buried by the advance of that beach toward the land.

The last event in the geologic history of the region was a downward movement, which is still in progress. It is this which has produced the estuaries and tide-water marshes that form conspicuous features of the existing topography. At the present time the waves of the Atlantic Ocean and Chesapeake Bay are at work tearing away the land along their margins and depositing it on a subaqueous platform or terrace. This terrace is everywhere present in a more or less perfect state of development, and may be observed not only along the exposed shores, but also on passing up the estuaries to their heads. The materials which compose it are varied, depending both on the detritus directly surrendered by the land to the sea and on the currents which sweep along the shore. On an unbroken coast the mate-

rial has a local character, while in the vicinity of a river mouth the terraces are composed of debris contributed from the entire river basin.

Besides building a terrace, the waves of the ocean and bay are cutting a sea cliff along their coast line, the height of the cliff depending not so much on the force of the breakers as on the relief of the land against which the waves beat. A low coast line yields a low sea cliff and a high coast line the reverse, and the one passes into the other as often and as abruptly as the topography changes, so that along the shore of Chesapeake Bay, high cliffs and low depressions occur in succession.

In addition to these features, bars, spits, and other shore formations of this character are being produced. If the present coast line were elevated slightly, the subaqueous platform which is now in process of building would appear as a well-defined terrace of variable width, with a surface either flat or gently sloping toward the water. This surface would everywhere fringe the shores of the ocean and bay, as well as those of the estuaries. The sea cliff would at first be sharp and easily distinguished, but with the lapse of time the less conspicuous portions would gradually yield to the leveling influences of erosion and might finally disappear altogether. Erosion would also destroy, in large measure, the continuity of the terrace, but as long as portions of it remained intact, the old surface could be reconstructed and the history of its origin determined.

THE MINERAL RESOURCES OF PRINCE GEORGE'S COUNTY

By

BENJAMIN L. MILLER.

INTRODUCTORY.

The mineral resources of Prince George's County are neither extensive nor especially valuable, but the county contains some deposits that are of considerable economic importance, although they have not hitherto been very largely worked. Among the most important are clays, sands, gravels, building stone, glauconitic and shell marls, diatomaceous earth, and iron ore. In addition the soils contribute much to the value of the region, which is primarily an agricultural one, and abundant supplies of water, readily obtainable in almost every portion of the county, form a further part of its mineral wealth.

THE NATURAL DEPOSITS.

THE CLAYS.

Next to the soils the clays constitute the most valuable economic deposits of Prince George's County. As already stated in the discussion of the stratigraphy of the region, several of the formations contain considerable quantities of clay. These argillaceous beds are rather generally distributed throughout the county, but, so far as known, have in recent years been worked only in the vicinity of Washington. In colonial days bricks were made at a number of points throughout the region. The clays are found in each series of deposits represented in the region. For convenience they may be

discussed under the headings Cretaceous, Eocene and Miocene, and Lafayette and Pleistocene clays.

Cretaceous Clays.—The clays of the Potomac group are the most valuable within the region under consideration. Each formation of the group contains deposits of clay that are suitable for a variety of uses. Some clays from the Patuxent have been employed for the manufacture of common brick, fire brick, and terra cotta; the Arundel contains clays adapted to the manufacture of common brick, terra cotta, sewer pipes, and pottery; the Patapsco with its great variety of clays furnishes material suitable for the manufacture of common brick, fire brick, and other refractory ware, sewer pipes, and pottery; and the somewhat less argillaceous Raritan formation contains clays adapted to the manufacture of common brick, terra cotta, and fire brick.

Eocene and Miocene Clays.—Although argillaceous beds occur very commonly in the Eocene and Miocene strata of the county, they are generally too sandy to be of much economic importance. Considerable lime, derived from the numerous fossil shells which are either generally distributed throughout the sandy clay or concentrated in definite shell beds within the formations, also render these clays of less value. They are, however, very accessible, being exposed in the cliffs along the Patuxent River and in the valleys of tributary streams, and if a way of utilizing them should be discovered, they could be obtained in great quantities at little expense. The pink clay at the base of the Nanjemoy formation, known as the Marlboro clay, is the most valuable deposit of this group. It is about 25 feet thick and is exposed at many places in the stream valleys between Upper Marlboro and Piscataway. The clay is fairly plastic and no doubt could be used for making pressed brick, but is not plastic enough and is, besides, rather too sandy for pottery.

Lafayette and Pleistocene Clays.—As already stated, the Lafayette, Sunderland, Wicomico, and Talbot formations are generally composed of coarse materials at the base of the deposits, with a rather persistent loam cap which marks the last stage of deposition during each particular submergence. This surficial loam, which is very

similar in all four formations, has been extensively used for the manufacture of brick at many places in Virginia, the District of Columbia, Maryland, and southeastern Pennsylvania. It is generally not more than 3 or 4 feet in thickness, yet, because of its position, many beds no more than 1 or 2 feet thick can be worked with profit. The loam is widely distributed throughout the county and, though not quite coextensive with the formations of which it forms a part, it is present in almost every locality where the Lafayette and Pleistocene formations occupy flat divides that have not suffered much erosion since their deposition. In general the surface loam is adapted only to the manufacture of the common varieties of brick and tile, but in some places it is suitable for making a fair quality of paving brick. In this region the surface loam from the Talbot and Wicomico formations has been utilized at several different times for the manufacture of brick in the eastern part of Washington, near Anacostia River.

THE SANDS.

Inasmuch as the arenaceous phase predominates in almost every Coastal Plain formation represented in the region, Prince George's County contains an unlimited supply of sand. The sand of the Pleistocene and Lafayette formations is used locally for building purposes, but as it is so readily obtainable in all parts of the region no large pits have been opened.

In some places the quartz sands of the Miocene seem to be pure enough for glass making, suggesting the Miocene glass sands so extensively exploited in southern New Jersey, although they have never been used in that way in this region. Careful chemical analyses and physical tests, which have not been made, would be required to determine their usefulness in this industry.

The Magothy sands in the vicinity of Anacostia have long been worked and at present the most extensive sand pits of the region are opened in deposits of this age a short distance south of Anacostia. The sand is used for building and filtering purposes. In certain

places the Potomac deposits contain molding sand of fair grade, but it has not been used to any great extent.

Locally the Lafayette and Pleistocene sands are rich in ferruginous matter, which in some places cements the grains together, forming a ferruginous sandstone. Sands of this character possess a distinct value for road-making purposes, as they pack readily and make a firm road bed. Where the material can be easily obtained in large quantities, good roads can be very economically constructed with it

THE GRAVELS.

The Pleistocene, Lafayette, and Potomac formations contain numerous beds of gravel widely distributed throughout the region. Those of the Pleistocene and Lafayette deposits are generally rich in iron, which acts as a cementing agent, thus rendering them of considerable value as road metal. There are numerous gravel pits in the eastern part of the District of Columbia in deposits belonging to the Sunderland and Lafayette formations, and elsewhere in the vicinity of Washington there are smaller pits in deposits of Wicomico and Talbot age.

THE BUILDING STONE.

Prince George's County contains few beds of building stone of much importance, yet in places materials occurring within the region have been used locally. The granite-gneiss is the best building stone of the region and furnishes good material for foundations and other rough work. It is schistose and consequently can not be obtained in large masses, but for that reason can be very easily quarried. Some of the more massive beds furnish stones suitable for building, and in places, where the beds are thinner and more micaceous, flagstones can be obtained.

Although the Coastal Plain formations of the region are composed almost entirely of unconsolidated materials, yet locally indurated beds are not uncommon. In the absence of any better stone these indurated ledges furnish considerable material for the construction of foundations and walls. The best stone of this class is the firmly

cemented white sandstone occurring in the Raritan formation about 1 mile north of Collington. The shell beds of the Aquia in the vicinity of Upper Marlboro are so firmly consolidated that they furnish building stone, which though of poor grade is nevertheless suitable for rough work. The gravel bands of the Lafayette and Pleistocene are, in many places, so firmly cemented by iron oxide as to form pebble conglomerates of considerable strength.

THE MARLS.

Glaucinite Marls.—The Eocene and Upper Cretaceous formations of the county are rich in deposits of glauconitic marls, which are of value as fertilizers. From New Jersey to North Carolina such deposits have been worked spasmodically since the early part of the last century, when their value was first determined, yet their importance in enriching the soil has never been generally recognized. They consist of quartz sand with an admixture of many grains of glauconite, a soft green mineral which is essentially a hydrous silicate of iron and potassium. On account of the glauconite, the marls are green in color and are commonly known as “greensand marls.” They are rich in calcium carbonate derived from the shells which are abundant in the deposits, and chemical analyses usually show the presence of small amounts of mineral phosphates. The marls thus contain three important plant foods—potash, lime, and phosphates. Altogether these constitute only a small percentage of the entire content of the deposits, yet wherever the marls can be obtained at low cost, they furnish economical means for increasing soil fertility. Where the glauconite marls have been used it is claimed that their beneficial effects is much more lasting than that obtained by means of artificial fertilizers. Within the county many Eocene and Upper Cretaceous beds rich in glauconite outcrop along the sides of the stream valleys, extending in a belt diagonally across the county from the Patuxent River to Mattawoman Creek.

Shell Marls.—The shell marls of the Miocene and Eocene formations also possess valuable fertilizing properties for soils deficient in lime. In some places the shells are mixed with so much sand that

the lime forms only a small part of the deposit, but in others the amount of lime exceeds 90 per cent. Experiments show that better results have been obtained by the use of shell marl than by that of burned stone lime. The marl acts both chemically and physically and has a beneficial effect on both clayey and sandy soils. So far as known, the shell marls of this region have not been utilized, although they are well developed in many localities in the southern part of the county.

THE DIATOMACEOUS EARTH.

The principal workings of diatomaceous earth are at Lyons Creek, on the Anne Arundel side of the Patuxent River, although a bed of the material occurring at the base of the Calvert formation extends entirely across the southeastern portion of the county. Diatomaceous earth, on account of its porosity and compactness, is used in water filters and as an absorbent in the manufacture of dynamite. It is reduced readily to a fine powder and makes an excellent base for polishing compounds, while its nonconductivity of heat makes it a valuable ingredient in packing for steam boilers and pipes and in the manufacture of safes, the latter being the principal use to which it is put. It has been thought that this earth might be of use in certain branches of pottery manufacture which require refractory materials that have no color when burned. Heinrich Ries tested a sample of diatomaceous earth from Lyons Creek at cone 27 in the Deville furnace and found that the material fused to a drop of brownish glass. Its nonrefractory character is thus clearly demonstrated.

THE IRON ORE.

The Arundel formation in Maryland has long been known as the important iron-bearing member of the Potomac group and many mines have been worked in this formation in Prince George's, Anne Arundel and Baltimore counties. In colonial times these mines were of the greatest importance and many of the cannon used in the Revolution were made from Potomac iron ores. In recent years, how-

ever, these mines have decreased in importance, as most of them have been unable to compete with the Lake Superior ores and at the present time the only furnace using these ores is located at Muirkirk in the northern part of the county. The numerous immense pits now filled with water that can be seen in this region furnish evidence of the large quantity of ore that has been removed though the present operations are rather small.

The Muirkirk furnace has been in almost continuous use since 1847, and during that time has produced a great quantity of high-grade pig iron. After having been closed three years it was reopened in May, 1909, and is now producing about 400 tons of pig iron per month from about 1,200 tons of ore.

The ore is primarily an iron carbonate ore, though much of it has been altered to limonite or hematite near the surface. The oxidized ore is commonly called brown ore, while the carbonate ore is called white ore. The various stages of alteration can be readily seen in many specimens that have a shell of limonite or hematite with a central core of siderite. In other cases the alteration has affected the whole mass and no iron carbonate remains.

The ore occurs in the form of flattened irregular nodules arranged in rather definite layers in compact plastic clay. In certain cases the nodules are in close contact and there is a persistent band of iron ore, but in other places considerable clay occurs between the ore masses. In most mines there are several layers of the iron ore separated by beds of clay of varying thickness. The ore layers are seldom more than 12 to 14 inches thick. Where the ore is mainly iron carbonate the color of the clay is generally buff to drab, but where the ore has been oxidized the clay is colored red and yellow. Considerable lignite is contained in the clays associated with the ore and, in places, the ore itself contains pieces of lignite. Such ore is usually discarded because of the iron pyrite which it is apt to contain. It is well known that lignite acts as a precipitating agent of iron sulphide carried in solution and it is not uncommon to find pieces of lignite coated with iron pyrite.

The Arundel iron ore does not contain as high a percentage of iron as many of the iron ores used in this country, the average ore

running from 40% to 45% of metallic iron. Phosphorus and sulphur are unusually low, while manganese and silica are high. In one place a deposit of manganese ore has been found associated with the iron ore.

The ore is mined in a very primitive manner, all the labor being done by hand, and the ore hauled direct to the furnace. The usual method of working is by open pits, but in some cases the ore is removed through slope tunnels and shallow shafts, where the covering of barren clay is too thick to be profitably removed. In the tunnels and shafts very little timbering is required. Practically no capital is necessary for this kind of mining and most of the men engaged in the operations are lessees who pay a royalty of about 35 cents per ton to the owner of the land. In most places the operators are able to make fair wages, but no extensive mining can be done under these conditions. When the overburden becomes great the mine is abandoned and new openings made, so that it is not advisable to represent the working mines on the map. It is sufficient to say that they are all within a few miles of Muirkirk and Contee. At the furnace the ore is first roasted in order to eliminate any sulphur and also to convert the carbonate ore to the form of oxides.

The pig iron produced at Muirkirk has long been known for its tensile strength, and for this reason commands a higher price than any other pig iron manufactured in this country. There is a ready market for the product, which is used exclusively in the manufacture of special articles in which great strength is required. It has been used extensively by the United States government in the manufacture of cannon and is also in demand for car wheels, cylinders and various special kinds of steel. The claim is made by the proprietors of the furnace that their product is the strongest pig iron produced in the United States. The slag has been used as road metal in the vicinity of Muirkirk, and at the present time is being shipped elsewhere for this purpose.

THE PETROLEUM AND NATURAL GAS.

Rumors have been circulated at various times of the discovery of petroleum and natural gas at several different places within the

county. Although many of these rumors have been without foundation, small amounts of oil and gas have been observed in some places during the sinking of wells and in the vicinity of streams where there is seepage from porous beds. The gases generated by decaying vegetation have been mistaken in certain cases for natural gas, and the iridescent film of limonite that often appears on the surface of stagnant water in swamps and bogs has been supposed to be petroleum.

Borings have been made about 2 miles west of Annapolis in Anne Arundel County and about 1 mile south of Meadows in the search for oil and gas, but only traces were found. The Meadows well was sunk to a depth of 1511 feet, in all probability nearly to the crystalline rocks, thus practically proving the absence in that place of any considerable amounts of either of these materials. It is not probable that either petroleum or natural gas in paying quantities will be found within the limits of the county.

THE WATER RESOURCES.

The water supply of Prince George's County is found in the streams and wells of the district. Many of the streams have been used at various times to furnish power for small mills, but little use has been made of them as sources of water supply. Washington obtains its water supply at a point some distance beyond the western boundary of the county. Laurel draws its supply of water from a small tributary of the Patuxent River. With the exception of the residents of these two cities the inhabitants of the region derive their water supply from springs and wells. The wells are divided into two classes—shallow dug wells and deeper bored wells, the deeper usually furnishing artesian water.

SPRINGS.

The gently sloping strata, the alternation of porous and impervious beds, and the great amount of dissection by streams which the region has undergone, all contribute to the formation of springs along the valley slopes. From these springs many of the inhabitants obtain

their entire supply of water, which is usually of excellent character. The spring water, as also that in wells, is in places highly charged with mineral matter, particularly iron, sulphur, and salt, and some such waters have been placed on the market. The most important mineral springs of the county from which waters have been sold are the Bladensburg Spa at Bladensburg and the Algonquin Springs at Oxon.

SHALLOW WELLS.

Nearly all the water supply of the county is derived from shallow wells, varying in depth from 15 to 35 feet. The water is contained in the rather coarse sand or gravel bed so commonly forming the basal stratum of the Pleistocene and Lafayette deposits. So generally is this the case that the depth of the shallow wells is usually a very good indication of the thickness of the surficial deposits. The surface water very readily penetrates the rather coarse surface materials until it reaches the less permeable underlying sedimentary or crystalline rocks. While some of it continues its downward course into these harder rocks a great deal flows along on their upper surface until it finds its way gradually into the streams. Hence wells sunk to this level are practically assured of a supply of water which, while seldom large in flow, is in seasons of average rainfall capable of furnishing sufficient water for ordinary purposes. Such shallow wells are necessarily dependent almost entirely on the amount of water which percolates through the Columbia and Lafayette deposits after rain storms, and are thus apt to be affected by droughts. After periods of heavy rainfall the water may rise in the wells within a few feet of the surface and then is very roily. At other times the wells may become dry, yet this does not often occur because of the fairly equable distribution of rainfall during the year. The supply is less variable over the broad divides or on level ground, where water is always nearer the surface, than in the regions of narrow stream divides, where the water finds an easy exit to the streams. In some places on the narrow divides in proximity to the major streams, it is necessary to sink wells to the depth of 100 feet or more in order to obtain a permanent supply of water.

Most of the water of the shallow wells is obtained at the base of the Lafayette or Sunderland deposits, as each of these formations covers large areas in which the streams have not yet cut through to the underlying deposits. There are also a number of shallow wells in the Patuxent River valley that derive their water supply from the base of the Talbot formation.

The water of the shallow wells usually contains so little mineral matter in solution that it is known as soft water. In many wells, no doubt, it does contain organic matter, yet there is little evidence to show that the water on this account is unfit for drinking purposes.

ARTESIAN WELLS.

Since water is so readily procured at shallow depths in almost all sections of the county and few establishments in the region require a large supply, there have not been many attempts to obtain artesian water. The area in which wells may be driven with the expectation of discovering a pressure sufficient to force the water to the surface is restricted to land lying 20 feet or less above tide. In areas above this altitude pump wells can probably be had from the water-bearing strata enumerated in the succeeding paragraphs, the water rising under artesian pressure above the point where it enters the well, but not overflowing. The somewhat meager data obtained in this and adjoining regions indicate the occurrence of water at the horizons described in the following paragraphs:

Waters of the Crystalline Rocks.—The waters contained in the crystalline rocks of the Piedmont Plateau are not of especial importance in this region, since these rocks occur at or near the surface in a very small area. In the vicinity of Washington some wells obtain water from these rocks, but to the northwest of this county they yield an important water supply. In general water occurs at less definite horizons in the crystalline rocks than in the Coastal Plain deposits, and it is consequently much more difficult to predict the depth to which wells must be sunk to obtain a good supply.

Beneath the unconsolidated sedimentary deposits of Prince George's County crystalline rocks similar to those exposed at the

surface in the northwestern portion of the county undoubtedly occur. This underlying consolidated rock mass is frequently spoken of as "bed rock." In general the crystalline rocks are less permeable than the overlying deposits and consequently check the downward passage of the percolating soil water, which tends to flow along on their surface or to collect in depressions. The surface of these old rocks dips rather uniformly to the southeast at an average rate of more than 100 feet to the mile. Along this crystalline floor much water flows to lower levels, and it therefore marks a good water horizon. Several artesian wells in the Coastal Plain derive an unfailing supply of pure water from this level. In Washington and the near vicinity water is obtained at this horizon in several wells, of which those at St. Elizabeth's Asylum are the largest. Five of the six artesian wells that supply the water system of Hyattsville probably obtain water at this horizon, which is reached at a depth of 250 feet. Though the water will overflow, the yield is increased by pumping. These five wells, together with another less than half as deep, are all pumped together and yield 130 gallons a minute.

Throughout the greater portion of the county this crystalline floor can never be very important as a water horizon because of its great depth. It was not reached in a 1511-foot boring about 1 mile south of Meadows, and it is probable that it lies as much as 2000 feet below tide over a large portion of the county.

Waters of the Lower Cretaceous Formations.—The Potomac deposits contain many beds of coarse material that constitute good water-bearing strata. Some of these sand and gravel beds lie between impervious deposits and thus furnish the requisite conditions for flowing artesian wells. Within the District of Columbia the beds belonging to the Potomac group are the principal water-bearing formations. The water does not seem to come from any one horizon of wide distribution, as is shown by the varying depths at which it is reached and by the failure to obtain any water in these beds at certain places. Wells that were unsuccessful in finding a satisfactory supply of water were the 360-foot well at the ice works and the 133-foot well at the Mount Vernon apartment house. On the other hand, at Hyattsville and in the vicinity there are several wells with small

flow that derive their supply of water from Potomac strata at depths between 100 and 112 feet. At Bladensburg flowing wells with capacities ranging from 1 to 15 gallons a minute have been obtained at depths between 73 and 100 feet; at the plant of the National Capital Brewing Company there is a 103-foot well that yields from 100 to 130 gallons a minute; at Langdon a flow of 40 gallons a minute was obtained at a depth of 140 feet; at the Reform School water was encountered at a depth of 270 feet; and near Chesapeake Junction a well which formerly flowed but now has to be pumped obtains its supply of water at a depth of 350 feet. In adjoining regions the Potomac strata have yielded an abundant supply of water. At Annapolis, on the grounds of the United States Naval Academy, a well sunk to the depth of 601 feet penetrated eight water-bearing strata within the Potomac beds, from three of which water flowed out at the surface, 8 feet above tide. At the lowest horizon, between 587 and 601 feet, a flow of water of 75 gallons a minute is obtained. The water contains iron, but is of excellent quality when filtered.

Waters of the Upper Cretaceous Formations.—The sandy strata of the Raritan and Magothy formations are in many places water-bearing. The water is apt to be strongly impregnated with iron, and locally with sulphur; consequently it is less desirable than that obtained from the Potomac deposits. At Upper Marlboro several flowing wells with an average depth of about 225 feet obtain a good supply of water from the Magothy. In some of the wells the amount of mineral matter in solution renders the water somewhat undesirable for drinking purposes, while in others the mineral matter seems to be present only in very small amounts. The Naval Academy well at Annapolis obtained flowing water from the Magothy at a depth between 180 and 220 feet, but as the supply was not sufficient the well was sunk deeper.

In New Jersey considerable artesian water has been obtained from the greensand deposits of the Upper Cretaceous. In Prince George's County no artesian wells are known in which the supply of water is obtained from the Matawan or Monmouth deposits. These are in general more porous than those of the Magothy or Potomac forma-

tions and contain fewer clay bands, so that the water passes more readily to lower levels.

Waters of the Eocene Formations.—The character of the Eocene beds is in the main similar to that of the Upper Cretaceous. More clay members are present, however, and consequently conditions for flowing wells are more favorable. The water is almost everywhere heavily charged with iron, and sulphur is also present in places. In this county no flowing wells obtain their supply of water from Eocene strata, but in the adjoining counties, particularly along the Bay shore of Anne Arundel County, many flowing wells obtain moderate flows of fairly good water from horizons within both the Aquia and Nanjemoy formations.

Waters of the Miocene Formations.—In the southern counties of the State, particularly in Calvert and St. Mary's, important water-bearing strata of Miocene age have been found to yield an abundant supply of excellent artesian water. Within Prince George's County, however, the Miocene strata lie so high that there is little head to the water contained in them, and flowing wells do not occur. Some shallow wells in the southern portion of the county probably derive their water supply from Calvert strata that in St. Mary's County yield artesian water

BIOGRAPHY

Benjamin Leroy Miller was born near Sabetha, Kansas, April 13, 1874. His early education was received in the public schools and in the Preparatory Department of Washburn College, Topeka. He entered the Freshman class of the University of Kansas at Lawrence in the fall of 1892. In 1897 he received the degree of A. B. From January, 1897, until June, 1900, he held the chair of Biology and Chemistry in Penn College, Oskaloosa, Iowa. He entered the Johns Hopkins University in October, 1900. Since coming to this University he has pursued work in Geology and Biology under Professors Clark, Reid, Mathews, Doctors Shattuck and Fassig, and Professor Brooks. During the year 1900-01 he held a University Scholarship, was appointed Fellow the following year, and at present is Fellow by Courtesy.

The summer of 1896 was spent by him in geological work in western Kansas under the direction of the Kansas University Geological Survey and the State Board of Irrigation. In the summer of 1898 he joined a party from the University of Chicago for geological field work in Yellowstone Park. In 1899 he was employed by the Iowa Geological Survey in areal field work. The past three summers he has spent in geological work in the Coastal Plain region of Maryland under the direction of the Maryland Geological Survey.

January, 1903.



MAP OF PRINCE GEORGE'S COUNTY AND DISTRICT OF COLUMBIA SHOWING THE GEOLOGICAL FORMATIONS

MARYLAND GEOLOGICAL SURVEY,

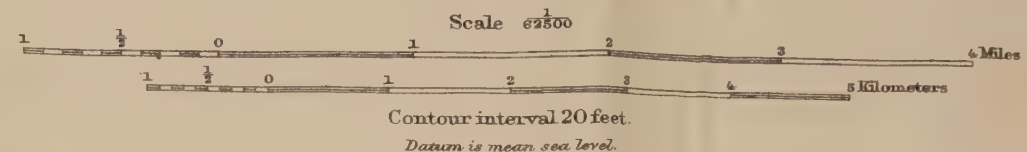
WM. BULLOCK CLARK, STATE GEOLOGIST.

IN CO-OPERATION WITH

U.S. GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

1911



LEGEND

With descriptions of the geological formations

PLEISTOCENE

Pct Talbot
Clayey loam, occupying upper portion of formation, carrying gravel layers and scattered boulders; lower half composed of clay, sand, gravel and boulders.

Pcw Wicomico
Clay loam, occupying upper part of formation, carrying gravel layers and scattered boulders; lower half composed usually of clay, sand, gravel and boulders.

Pcs Sunderland
Loam and sand predominant in the upper portion, sand and gravel in the lower part of formation.

PLIOCENE (?)

Ni Lafayette
Reddish and yellowish sands and gravel locally indurated to sandstone and conglomerate.

MIOCENE

Moch Choptank
Clay, sandy-clay, sand, marl.

Mcc Calvert
Clay, sandy-clay, sand, marl; argillaceous earth.

Eocene

En Nanjemoy
Clay, sandy-clay; sand, glauconite, marl.

Es Aquia
Greensand, sand, and indurated sand.

CRETACEOUS

Kmo Monmouth
Greensand and sand, locally indurated.

Kma Matawan
Greenish-black sandy clay, containing green concretions and lignite.

Km Magothy
Lignitic and white sands and dark laminated clay.

Kr Raritan
Interbedded sand, sandy clay, and clay; sands at times indurated.

Kpa Patuxent
Interbedded clay and locally indurated sand.





